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Office of Radiation Programs

XUM

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 12, Number 5, May 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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ENVIRONMENTAL PROTECTION AGENCY
William D. Ruckelshaus, Administrator

Reports

Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and Their Support Facilities, 1970

M.E. Miles, J. J. Mangeno, and *R. D. Burke*[1]

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm adequacy of waste disposal limits and procedures. The total radioactivity discharged into all ports and harbors was 0.024 curies in 1970, less than one hundredth the total annual discharges of the early 1960's. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt-60 show that (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment, and (3) low-level cobalt-60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years; these levels have decreased in recent years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the health and safety of the general public.

The radioactivity in wastes discussed in this report originates in the pressurized water reactors of U.S. Naval nuclear-powered ships. As of the end of 1970, there were 92 nuclear-powered submarines and four nuclear-powered surface ships in operation. Construction, maintenance, overhaul, and refueling of these nuclear propulsion plants involve nine shipyards, eleven tenders, and two submarine bases. This report first describes disposal of radioactive liquid wastes, then solid wastes. The final section discusses monitoring of the environment to determine the effects of radioactive discharges. This report brings the information in the Navy's 1959 report up to date (*1*).

Radioactive liquid waste disposal

In the shipboard reactors, pressurized water circulating through the reactor core picks up the heat of nuclear reaction. Reactor cooling water circulates through a closed piping system to heat exchangers which transfer the heat to water in a secondary steam system isolated from the primary cooling water. The steam is then used as the source of power for the propulsion plant as well as for auxiliary machinery. Discharges of radioactivity from ships occur primarily when reactor coolant water expands as a result of being heated to operating temperature; this coolant passes through a purification system ion-exchange resin bed prior to discharge.

Liquid wastes discharged by support facilities result from operations such as draining shipboard reactor systems, decontaminating piping systems contaminated with radioactivity, and laundering anticontamination clothing worn by personnel. These facilities are equipped with processing systems to remove most of the radioactivity from liquid wastes prior to discharge into harbors.

The principal source of radioactivity in liquid wastes is from trace amounts of corrosion and

[1] Nuclear Power Directorate, Naval Ship Systems Command, Department of the Navy.

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wear products from reactor plant metal surfaces. Radionuclides with half-lives greater than one day in these corrosion and wear products include tungsten-187, chromium-51, hafnium-181, iron-59, iron-55, zirconium-95, tantalum-182, manganese-54, cobalt-58, and cobalt-60. The predominant and also longest lived of these is cobalt-60, which has a 5.3 year half-life; cobalt-60 also has the lowest concentration value for water listed by organizations which set radiological standards (*2–4*) for these corrosion and wear radionuclides. Conservatively, therefore, radioactive waste disposal is controlled by assuming that all the long-lived radioactivity is cobalt-60.

The total amounts of long-lived radioactivity discharged into harbors and seas within 12 miles from shore during the past 5 years are listed in table 1, which updates information in references 5 through 9. Included are data from U.S. Naval nuclear-powered ships and from supporting shipyards, tenders, and submarine bases. Locations listed in table 1 include operating bases and home ports in the United States and overseas which have been visited by Naval nuclear-powered ships. The quantities of radioactivity listed in this table are reported as if the entire radioactivity consisted of cobalt-60, the predominant long-lived radionuclide.

Although this table shows both gallons and curies discharged, the curie data are the more important. In 1970, the gallons shown in table 1 for most of these organizations are no more than many single U.S. homes discharge to their sewage systems each year.

The table shows that nearly all the radioactive discharges occur where shipyards are overhauling nuclear-powered ships. In 1970, for example, a total of 0.024 curie was discharged into all harbors, including those outside the United States. Essentially all of this came from shipyards overhauling nuclear-powered ships. Less than one percent of the total was discharged into all other harbors entered by U.S. Naval nuclear-powered ships in 1970.

This total radioactivity discharged into harbors is less than the U.S. Public Health Service (PHS) (*10*) reports most individual electrical power-generating nuclear reactors discharge each year. Evaluation by PHS (applicable divisions of which were incorporated into the Environmental Protection Agency (EPA) late in 1970) of the small radioactive discharges from electrical power-generating reactors shows that these discharges caused little or no increase in environmental radioactivity.

The 0.024 curie total from the Navy nuclear propulsion program is less than the 1 curie per year the U.S. Atomic Energy Commission (AEC) regulations (*2*) permit a licensee to discharge into a single sanitary sewage system.

Procedures for liquid wastes in harbor

Discharge limits for radioactive liquid wastes from U.S. Naval nuclear-powered ships and their support facilities are consistent with applicable recommendations issued by the Federal Radiation Council (incorporated into the Environmental Protection Agency late in 1970) AEC, National Council on Radiation Protection and Measurements (NCRP), International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA), and National Academy of Sciences-National Research Council (NAS-NRC) (*2–4, 11–14*). In consonance with these recommendations, the policy of the U.S. Navy is to minimize the amounts of radioactivity discharged within 12 miles from shore including into harbors. Keeping discharges small minimizes the radioactivity available to build up in the environment or to concentrate in marine life. To implement this policy of minimizing discharges, the Navy has issued standard instructions defining the radioactive waste disposal limits and procedures to be used by U.S. Naval nuclear-powered ships and their support facilities. These instructions were reviewed and concurred with by the U.S. Public Health Service and the U.S. Atomic Energy Commission.

To achieve low discharges, the waste disposal procedures and limits used in the Navy nuclear propulsion program are more stringent than in the preceding references. The following are some of the procedures required by the Navy in shipyards:

a. Shipyard management at all levels is required to be involved in control of radioactive liquid waste.

b. Liquids are segregated to minimize volumes required to be processed as radioactive. Liquids with different chemical contents are collected

Table 1. Radioactive liquid waste discharged to harbors from U.S. Naval nuclear-powered ships and their support facilities for 1966 through 1970[a,b,c]

Facility	1966		1967		1968		1969		1970	
	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies
Portsmouth, N.H; Naval Shipyard	155	0.011	265	0.012	171	0.006	87	0.002	68	0.002
Groton-New London, Conn; Electric Boat Division, tender at State Pier, and submarine base	1,274	.025	606	.011	469	.006	615	.006	359	.004
Newport News, Va; Newport News Shipbuilding	1,581	.055	1,533	.034	1,146	.025	870	.022	1,466	.013
Norfolk, Va; Naval Shipyard and tender	1,051	.023	1,784	.034	184	.004	102	.005	98	.001
Charleston, S.C; Naval Shipyard and tenders	369	.034	320	.011	227	.004	131	.001	58	<.001
Pascagoula, Miss; Ingalls Nuclear Division	<1	<.001	6	<.001	9	<.001	8	<.001	7	<.001
San Diego, Calif; tenders at Ballast Point	18	.001	28	.001	<1	<.001	<1	<.001	<1	<.001
Long Beach, Calif; Naval Shipyard and Base	8	<.001	<1	<.001	<1	<.001	2	<.001	<1	<.001
Vallejo, Calif; Mare Island Naval Shipyard	270	.187	140	.001	391	.027	80	.001	121	.002
Bremerton, Wash; Puget Sound Naval Shipyard	54	<.001	246	.002	182	.001	152	.001	136	<.001
Pearl Harbor, Hawaii; Naval Shipyard and submarine base	654	.031	683	.008	886	.006	1,279	.008	258	.002
Apra Harbor, Guam	39	<.001	42	.002	26	.001	<1	<.001	<1	<.001
All other harbors, United States and foreign	178	.013	<1	<.001	<1	<.001	<1	<.001	<1	<.001
Totals	5,651	0.381	5,653	0.116	3,691	0.081	3,326	0.048	2,571	0.024

[a] Radioactivity data have been standardized to cobalt-60 (are reported as if the entire radioactivity consisted of cobalt-60) and excludes tritium. Volumes are prior to dilution.

[b] A total of 0.02 curies was discharged into the river at Quincy, Mass., from 1961 through March 1969 when all work on U.S. Naval nuclear-powered ships was discontinued at General Dynamics, Quincy Division. A total of 0.01 curies was discharged into the river near Camden, N.J., from 1960 through June 1967 when all work on U.S. Naval nuclear-powered ships was discontinued at New York Shipbuilding Corporation.

[c] Slight differences in volumes and radioactivity data from past reports result from using more significant figures in this table. Volumes less than 500 gallons are shown as <1 thousand. Curies less than 0.0005 are shown as <0.001

separately to ensure that the most effective waste treatment is used. Dilution is not permitted as a means of processing wastes.

c. Several stages of filtration using various pore-size filters are used to remove small-size radioactive particles in liquid waste. Ion exchange resin and activated carbon are normally used to remove radioactivity from liquid wastes.

d. Each shipyard has a limit specified for the total amount of radioactivity to be discharged during the year.

e. Samples are collected during processing to ensure that liquid wastes are far below the permissible water discharge limits in reference 2. Limits used by shipyards are lower than in reference 2.

f. To ensure against operational error, liquid wastes which have been completely processed are transferred to a final clean tank and again sampled prior to discharge. Discharge from this tank is through a final filter.

g. Each discharge requires formal approval of a discharge permit signed by a designated senior radiological control person.

h. An independent organization within the shipyard audits all aspects of radioactive waste processing. This audit group is separate from the radiological control organization which monitors the actual waste processing work.

i. Audits are also performed by representatives from Naval Reactors headquarters who are assigned full time at each shipyard.

j. To ensure absolute compliance with even the smallest detail of operating procedures, each discrepancy found is brought to management attention for action. Aggressive action on such minor items prevents incidents from occurring.

Other radionuclides

Reactor coolant also contains short-lived radionuclides with half-lives of seconds to hours. The highest concentrations in reactor coolant are

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from nitrogen-16 (7 second half-life), nitrogen-13 (10 minute half-life), fluorine-18 (1.8 hour half-life), argon-41 (1.8 hour half-life), and manganese-56 (2.6 hour half-life). For the longest-lived of these, about 1 day after discharge from an operating reactor, the concentration is reduced to one thousandth of the initial concentration, and in about 2 days, the concentration is reduced to one millionth. Most discharges from ships occur during heating up prior to power operation of the reactor, when short-lived radionuclides are at low concentrations in coolant. Total short-lived radioactivity in such a discharge is less than 0.001 curie. Because of their small amounts and rapid decay, short-lived radionuclides are less important than long-lived radionuclides for waste disposal considerations.

Fission products produced in the reactor are retained (metallurgically bound) within the fuel alloy. The fission gases, krypton and xenon, are also retained within the fuel elements. However, trace quantities of naturally occurring uranium impurities in reactor structural materials release small amounts of fission products to reactor coolant. The concentrations of fission products and the volumes of reactor coolant discharged are so low, however, that the total radioactivity attributed to the long-lived fission product radionuclides, strontium-90 and cesium-137, in discharges from U.S. Naval nuclear-powered ships and their support facilities has been less than 0.001 curie per year for all harbors combined. Fallout of these same fission products has often been more than this in one rainfall in a single harbor.

Small amounts of tritium are formed in reactor coolant systems as a result of neutron interaction with the approximately 0.015 percent of naturally occurring deuterium present in water and other nuclear reactions. Although tritium has a 12 year half-life, the radiation produced is of such low energy that the radioactivity concentration guide issued by the ICRP and AEC and by other standard-setting organizations is 100 times higher for tritium than for cobalt-60. This tritium is in the oxide form; it does not concentrate significantly in marine life or collect on sediment since it is chemically indistinguishable from water.

Tritium is naturally present in the environment because it is generated by cosmic radiation in the upper atmosphere. Reference 15 reports that the production rate from this source is about 6 million curies per year, which through rainfall causes a tritium inventory in the oceans of about 100 million curies. Because of this naturally occurring tritium, large discharges of tritium would be required to make a measurable change in the background tritium concentration.

The total amount of tritium discharged during each of the last 5 years from all U.S. Naval nuclear-powered ships and their supporting tenders, bases, and shipyards has been less than 200 curies. Most of these discharges have been in the ocean more than 12 miles from shore. This total tritium discharged from the entire nuclear Navy is less than a single, typical, electrical generating, pressurized water reactor-type, nuclear power station discharges each year (*10*). As described above, such discharges are too small to increase measurably the tritium concentration in the environment. Therefore, tritium has been excluded from the data in other sections of this report.

Liquid waste at sea

Radioactive liquid wastes are also discharged at sea under strict controls. These ocean discharges are consistent with recommendations that the Council on Environmental Quality made in 1970 to the President (*16*). Procedures and limits for ocean discharges have been consistent with recommendations made by the NAS-NRC (*12*) and by the IAEA (*13*). Ship discharges have contained much less radioactivity than these reports indicated would be acceptable. Total long-lived radioactivity, excluding tritium, discharged farther than 12 miles from shore by all U.S. Naval nuclear-powered ships and their supporting tenders is shown in table 2 for recent years.

Table 2. Radioactive liquid waste discharged at sea by U.S. Naval nuclear-powered ships and supporting tenders

Year	Quantity (thousand gallons)	Radioactivity (Ci)
1966	1,400	1.2
1967	1,520	1.3
1968	1,630	1.1
1969	1,570	1.7
1970	1,220	.8

Reactor coolant is purified through an ion-exchange resin bed. This resin becomes expended and periodically requires replacement. Expended resin has been discharged at sea, but this practice was discontinued during 1970. When discharged at sea, resin sinks and as it sinks, the radioactive ions in the resin are rapidly replaced by ions of the sea water. Some of the small radioactive particles in the resin bed are dispersed in sea water and the rest sink with the resin beads. The radioactivity is rapidly dispersed in the ocean due to motion of the ship during discharge and subsequent action of wind, waves, and ocean currents.

Resin discharge at sea was performed in accordance with procedures recommended in the NAS-NRC Publication 658, "Radioactive Waste Disposal from Nuclear-Powered Ships" (*12*). Consistent with these recommendations, Navy procedures for resin discharge at sea required that:

1. The ship be more than 12 miles from any land,
2. The water depth be greater than 1,200 feet,
3. The ship not be in known fishing areas, and
4. Other ships not be nearby and not be in the wake.

Publication 658 developed these procedures to assure no adverse impact on the environment if up to 300 nuclear-powered ships each discharge 400 curies of radioactivity every 2 months off the shores of the United States.

Table 3 summarizes resin discharges at sea during the last 5 years. These results show that the total radioactivity discharged in resin by the entire Navy each year has been less than envisaged in the NAS report for a single ship. Diluting this total radioactivity discharged in a year in a volume as small as 1 cubic-mile of seawater reduces the concentration of radioactivity to less than that which occurs naturally in the ocean. Continued effort by the Navy resulted in improvements in 1970 which have permitted discontinuing discharge of ion exchange resin at sea. Expended resin is now packaged for land disposal in AEC- or State-licensed burial grounds as solid radioactive waste.

Table 3. Radioactive resin disposal at sea by U.S. Naval nuclear-powered ships

Year	Cubic feet of resin	Radioactivity (Ci)
1966	119	439
1967	252	259
1968	196	126
1969	406	132
1970	150	60

Two U.S. Navy nuclear-powered submarines have been lost at sea in the Atlantic Ocean. The submarine THRESHER sank 10 April 1963, 100 miles from land in water 8,500 feet deep at latitude 41°45′N and longitude 65°00′W. The submarine SCORPION sank between 21 and 27 May 1968, 400 miles southwest of the Azores in more than 10,000 feet of water. The reactors used in all U.S. Naval submarines and surface ships are designed to minimize potential hazards to the environment even under the most severe casualty conditions such as actual sinking of the ship. First, the reactor core is so designed that it is physically impossible for it to explode like a bomb. Second, the reactor fuel elements are made of materials that are extremely corrosion resistant, even in sea water. The reactor core could remain submerged in sea water for decades without release of fission products while the radioactivity decays since the protective cladding on the fuel elements corrodes only a few millionths of an inch per year. Thus in the event of a serious accident where the reactor is completely submerged in sea water, the fuel elements will remain intact for an indefinite period of time and the radioactive material contained in these fuel elements should not be released. The maximum rate of release and dispersal of the radioactivity in the ocean, even if the protective cladding on the fuel were destroyed, would be so low as to be insignificant.

Radioactive material could be released from this type of reactor only, if the fuel elements were actually to melt and in addition, the high-strength, all-welded reactor system boundary were to rupture. The reactor's many protective devices and inherent self-regulating features are designed to prevent any melting of the fuel elements. Flooding of a reactor with sea water furnishes additional cooling for the fuel elements and so provides added protection against the release of radioactive material.

Radiation measurements, water samples, bottom sediment samples, and debris collected from the area where THRESHER sank were analyzed

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for radioactivity by various laboratories with highly sensitive equipment. Similarly, sea water and bottom sediment samples taken near SCORPION's hull were analyzed for radioactivity. None of these samples showed radioactivity above naturally occurring background levels and none showed evidence of radioactivity released from either THRESHER or SCORPION.

Solid radioactive waste disposal

During maintenance and overhaul operations, solid low-level radioactive wastes consisting of contaminated rags, plastic bags, paper, filters, ion exchange resin, and scrap materials are collected by nuclear-powered ships and their support facilities. High-level radioactive wastes are associated with expended reactor fuel, all of which are transferred to the AEC for processing. Solid materials from ships are not dumped at sea. They are packaged in a support facility or transferred to a shipyard for packaging. For ultimate disposal, the packaged solid radioactive wastes are shipped to burial sites licensed by the AEC or a State under agreement with the AEC since shipyards and shore facilities are not permitted to dispose of radioactive solid wastes by burial on their own sites. Table 4 summarizes total radioactivity and volumes of radioactive solid waste disposal for the last 5 years.

Because of efforts to minimize solid waste, total volumes have remained nearly constant in spite of increasing work caused by increasing numbers of ships. The average annual volume for the entire Naval nuclear propulsion program could be contained in a cube measuring 15 yards on a side. The radioactivity does not require excessively long-time care in the licensed burial grounds since the principal radionuclides do not have half-lives longer than 5 years. In 100 years, such radioactivity will have decayed to 1 millionth of the initial radioactivity. In less than 200 years, the total of all radioactivity in table 4 will have decayed to less than the amount of radioactivity in a single luminous watch dial.

Disposal of solid radioactive wastes at sea is prohibited by the U.S. Navy. There have been two special exceptions to this policy. First, on 8 April 1959, the radioactive reactor vessel and the reactor plant components removed from the sodium-cooled nuclear reactor plant in the submarine

Table 4. Radioactive solid waste from U.S. Naval nuclear-powered ships and their support facilities for 1966 through 1970[a,b]

Facility	1966		1967		1968		1969		1970	
	Thousand cubic feet	Curies	Thousand cubic feet	Curies	Thousand cubic feet	Curies	Thousand cubic feet	Curies	Thousand cubic feet	Curies
Portsmouth, N.H; Naval Shipyard	19	10	30	198	31	151	8	3	14	16
Groton, New London, Conn; Electric Boat Division, tender at State Pier and submarine base	15	1,093	5	17	4	21	8	328	12	140
Newport News, Va; Newport News Shipbuilding	7	9	17	702	14	10	17	382	28	312
Norfolk, Va; Naval Shipyard and tender	4	3	11	86	2	11	6	8	9	146
Charleston, S.C; Naval Shipyard and tenders	8	6	15	52	14	110	15	9	8	6
Pascagoula, Miss; Ingalls Nuclear Division	0	0	0	0	0	0	1	<1	0	0
San Diego, Calif; tenders at Ballast Point	1	<1	1	<1	1	8	<1	2	<1	1
Long Beach, Calif; Naval Shipyard and Base	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Vallejo, Calif; Mare Island Naval Shipyard	9	367	9	23	8	7	8	5	12	2
Bremerton, Wash; Puget Sound Naval Shipyard	1	1	14	193	14	48	11	42	18	1,327
Pearl Harbor, Hawaii; Naval Shipyard and submarine base	1	<1	1	1	3	6	4	3	5	4
Totals	65	1,489	103	1,272	92	372	78	783	106	1,954

[a] This table includes all radioactive waste from tenders and nuclear-powered ships. This radioactivity is primarily cobalt-60.
[b] Slight differences from past reports result from using different number of significant figures in this table. Volumes less than 500 cubic feet are reported <1 thousand and less than 0.5 curie is reported <1.

SEAWOLF were escorted by the U.S. Coast Guard to a disposal site in the Atlantic Ocean 120 miles off the east coast of the United States and sunk in 9,000 feet of water at latitude 38° 30′N and longitude 72°06′W. The disposal was conducted at a site approved for sea disposal of radioactive waste by AEC. This disposal site was used by other organizations for a number of years for radioactive waste (*16*). The SEAWOLF components containing approximately 33,000 curies of radioactivity were welded into a steel barge and scuttled. The low corrosion of this steel container in sea water and the method of packaging were designed to prevent any release of radioactivity to the surrounding sea. As of 1970, this radioactivity has decayed to less than 5,000 curies, essentially all cobalt-60.

The second exception was required for radioactive solid wastes from Pearl Harbor, since it was not feasible to establish a burial ground in the volcanic rocks of Hawaii. Therefore an ocean disposal area, 55 miles from shore, was selected with the agreement of the AEC, the PHS, and the Hawaii Department of Health. The Navy Hydrographic Office determined that normal ocean currents at this location are away from shore. Low-level radioactive waste packaged primarily in 55-gallon steel drums weighted with concrete were disposed of by Pearl Harbor Naval Shipyard in 15,000 feet of water at this location, as shown in table 5. The radioactivity in this waste was primarily cobalt-60. In June 1968, use of this ocean disposal area was discontinued by the Navy and wastes have since been shipped to an AEC or State licensed land burial ground in the continental United States.

Table 5. Solid radioactive waste disposal in the ocean at latitude 20°54′N, longitude 161°06′W

Year	Number of disposal operations	Volume (ft^3)	Radioactivity (Ci)
1963	1	1,647	0.5
1964	1	1,275	.7
1965	1	672	1.4
1966	1	682	.3
1967	2	1,134	1.0
1968	4	1,720	4.5
Total	10	7,130	8.4

Environmental monitoring

Environmental monitoring surveys for radioactivity are periodically performed in harbors where U.S. Naval nuclear-powered ships are built or overhauled and where these ships have home ports or operating bases. These surveys are performed to verify the adequacy of liquid waste disposal procedures and limits. To ensure thoroughness and objectivity these surveys are made as independent as practicable from waste disposal operations. Samples from each harbor monitored are also checked at least annually by an AEC laboratory to ensure that analytical procedures are correct and standardized. These AEC laboratory results have been consistent with shipyard results. As a further independent check of environmental monitoring, the PHS has conducted detailed surveys of selected harbors (*17,18*). The PHS has monitored the harbors at Charleston, S.C; Pearl Harbor, Hawaii; San Diego, Calif; Vallejo, Calif; New London, Conn; Newport News, Va; and Norfolk, Va. Navy monitoring results have been consistent with these PHS surveys.

The Navy monitoring program initally emphasized analyzing water because it is used by boats and swimmers and because fish live in this water. Surveys were conducted in the harbors before any radioactivity was discharged to establish base levels of gross beta radioactivity of harbor water in the vicinity of berths to be used by nuclear-powered ships and locations where support facilities might discharge processed water. Results showed that superimposed on the naturally occurring radioactivity of 0.3 picocuries of potassium-40 per milliliter of harbor water were large variations of other radioactivity from fallout. Rain water before much dilution in harbor water sometimes has measured more than 100 times higher than this. In addition, rates of introduction of naturally radioactive radium, uranium, thorium, and their associated radionuclides varied. However, in more than 10 years of monitoring sea water for gross beta radioactivity, commencing in 1954 in New London, Conn., and extending to other ports, no increases in water radioactivity were ever discovered which could be attributed to operation of nuclear-powered ships or their support facilities.

Although the general background radioactivity measurements previously used would indicate presence of radioactivity before exceeding

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concentrations permitted (*2*), more sensitive measurement techniques were adopted in 1965. Currently, five water samples are taken in each harbor once each quarter year in areas where nuclear-powered ships berth and from upstream and downstream locations. These samples are analyzed for gross gamma radioactivity and for cobalt-60 content. Procedures for analysis were selected to detect cobalt-60 if its concentration exceeds 0.1 picocurie per milliliter, which is 300 times lower than the AEC limit (*2*). No cobalt-60 has been detected in any of the 2,560 water samples from 20 harbors monitored.

Harbor bottom sediment contains many of the remnants of water pollution; the top layer is generally black and has an offensive odor from decomposing organic waste materials. Silt carried by rivers also deposits on harbor bottoms, building up in depth from less than 1 inch per year to more than 3 feet per year. In falling to the bottom, this silt carries radioactivity from the water to the bottom. Therefore, sampling of harbor bottom sediment became part of early Navy environmental monitoring programs to provide advance indication of radioactivity buildup in the harbor.

Initially, dried samples of harbor bottom sediment were measured for gross beta radioactivity. Results varied from 10 picocuries per gram of sediment to 300 picocuries per gram and varied widely from sample to sample and from month to month in a single harbor. However, analysis of these data showed no harbor had increased its general background radioactivity from operations associated with U.S. Naval nuclear-powered ships.

Commencing in 1963 at the Navy's request, the PHS made additional analyses of samples from some harbors to identify radionuclides present in sediment. These analyses showed that cobalt-60 was the predominant radionuclide added to sediment from nuclear reactor operations. Therefore, Navy monitoring procedures were changed to collect from each harbor 20 to 120 sediment samples once each quarter year. Standard 6-inch square samplers modified to collect only the top ½ to 1 inch of sediment are used for all sediment collection. The top layer was selected because it should be more mobile and more accessible to marine life than deeper layers. The samples are analyzed for gross gamma radioactivity and for cobalt-60. Results of the 3,070 sediment samples from harbors in the United States and possessions for 1970 are summarized in table 6. Comparison to previous environmental monitoring data (*5–9*) shows that environmental cobalt-60 levels have been steadily decreasing.

Table 6 shows that some samples taken near liquid waste discharge points show cobalt-60 radioactivity. However, the affected areas are small, and the total cobalt-60 present is small compared to natural radioactivity present in harbors.

The first data column in table 6 includes all

Table 6. Summary of 1970 surveys for cobalt-60 in bottom sediment of U.S. harbors where U.S. Naval nuclear-powered ships have been regularly based, overhauled, or built

Facility	Number of samples with cobalt-60 concentration			Total bottom area with cobalt-60 over 3 pCi/g[c] (km²)	Estimated total cobalt-60 in top layer of sediment[d] (Ci)
	<3 pCi/g[a]	3-30 pCi/g	>30-300 pCi/g[b]		
Portsmouth, N.H.; Naval Shipyard	176	0	0	0	ND
Groton, New London, Conn.; Electric Boat Division, State Pier, and submarine base	377	86	1	0.1	0.02
Newport News, Va; Newport News Shipbuilding	152	0	0	0	ND
Norfolk, Va; Naval Shipyard and Base	344	0	0	0	ND
Charleston, S.C; Naval Shipyard and Bases	382	0	0	0	ND
Pascagoula, Miss; Ingalls Nuclear Division	212	0	0	0	ND
San Diego, Calif; Navy Pier at Ballast Point	157	0	0	0	ND
Long Beach, Calif; Naval Shipyard and Base	158	0	0	0	ND
Vallejo, Calif; Mare Island Naval Shipyard	444	0	0	0	ND
Bremerton, Wash; Puget Sound Naval Shipyard	141	0	0	0	ND
Pearl Harbor, Hawaii; Naval Shipyard and submarine base	312	0	0	0	ND
Apra Harbor, Guam	128	0	0	0	ND

[a] Minimum detectable radioactivity is approximately 1 pCi/g. Results in units of pCi/cm² range from two to four times the value in pCi/g.
[b] No samples from any harbor were greater than 31 pCi/g.
[c] One square kilometer is approximately equal to 0.4 square mile. Areas with cobalt-60 over 3 pCi/g were in immediate vicinity of piers used for berthing nuclear-powered ships.
[d] Where total cobalt-60 in the surface sediment layer is less than 0.01 curies, ND is reported. Samples more than 1-foot-deep from several harbors show that total cobalt-60 present may be two to five times that measured in the surface layer.

samples with less than 3 picocuries of cobalt-60 per gram of sediment. These low levels are difficult to measure because the levels of radioactivity in sediment from other sources are much higher. The value of 30 picocuries per gram was selected for the top of the second range of data since it corresponds to the upper limit for exposure (*2,4*) even if consumed continuously by members of the general public. Although sediment cannot be consumed by humans, it might serve as a food source for marine life. Data on uptake of cobalt-60 from sediment by marine life obtained to date show that in the salt water harbor-bottom environments, no significant build-up of cobalt-60 occurs in marine life. Therefore, the third range of up to 300 picocuries per gram is selected as a range which would not cause members of the general public to receive radiation exposure approaching the values set (*2–4,14*). Concentrations of cobalt-60 up to 300 picocuries per gram are so low that the AEC does not require those who might possess them to be licensed. If concentrations higher than 300 picocuries per gram were to persist over substantial areas of a harbor bottom, further monitoring would be performed to determine if any of this radioactivity were being taken up by marine life for eventual consumption in food. Because of the low concentrations noted in table 6, monitoring of radioactivity in marine life has not been necessary as part of the routine environmental monitoring programs in these harbors.

References 19 and 20 contain evaluations by AEC laboratories of the effects on the environment from the accumulation near points of discharge of radionuclides from several other nuclear reactors. These reports conclude for these other reactors that radioactivity levels much greater than these shown in table 6 have caused no significant exposure to the general public.

An additional part of the environmental analyses has been to compare amounts of radioactivity measured in the environment with amounts discharged. For example, if 0.01 curies were discharged each year for more than 10 years into a single harbor, the maximum total inventory of cobalt-60 in this harbor will be 0.1 curies of cobalt-60, assuming none of this radioactivity is flushed out with river currents, tides, or dredging. If all this radioactivity were spread uniformly over a reasonable area of 1 square kilometer of the harbor bottom, the result would be less than 10 picocuries of cobalt-60 per square centimeter. This cobalt-60 will be distributed deeply through the sediment over the years, resulting in an average concentration less than 1 picocurie of cobalt-60 per gram of sediment. This is less than the amount of cobalt-60 which would be detected by present sensitive environmental monitoring techniques. Results of analyses such as these help confirm the environmental monitoring data of table 6 and confirm that the Navy's waste discharge limits are satisfactory.

In all monitored harbors, shoreline areas uncovered at low tide are surveyed twice per year for radiation levels with sensitive radiation detectors to determine if any radioactivity from bottom sediment washed ashore. All results were the same as background radiation levels in similar areas, 0.010 to 0.040 millirem per hour. Thus, there is no evidence in these ports that radioactivity from sediment is washing ashore.

Film badges are continuously posted at locations outside the boundaries of areas where radioactive work is performed. These films showed that radiation exposure to the general public outside these facilities was not above that received from natural background radiation levels.

Naval nuclear reactors and their support facilities are designed to ensure that there are no detectable discharges of airborne radioactivity to the atmosphere. Filtration equipment is installed in support facilities to ensure removal of airborne radioactivity without release to the atmosphere. Exhaust stacks at support facilities which could have discharged airborne radioactivity have been monitored. There were no discharges of airborne radioactivity to the atmosphere measured above concentrations normally present in the atmosphere.

In addition to the locations listed in table 6, environmental monitoring is performed by U.S. Navy submarine tenders which serve as operating bases for U.S. Naval nuclear-powered submarines in Rota, Spain, and Holy Loch, Scotland. Results of the surveys in the harbor at Rota, Spain, have not shown detectable cobalt-60 in harbor bottom sediment samples. In 1965 in Holy Loch, more cobalt-60 radioactivity than expected was detected in harbor bottom sediment and on shore-

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line mud flat areas uncovered at low tide. However, there had been no increase of harbor water radioactivity in Holy Loch above normal background levels. Joint U.S. and British assessments of survey results confirmed that radiation levels in the vicinity of the Holy Loch anchorage were far below those which were at all likely to cause an individual to receive radiation exposure approaching limits for members of the general public. Environmental monitoring during 1970 showed radioactivity levels in Holy Loch are steadily declining and are now less than half the levels in 1965.

Summary

The total radioactivity discharged into all ports and harbors from the U.S. Naval nuclear propulsion program was 0.024 curies in 1970.

No increase of radioactivity above normal background levels has been detected in harbor water where U.S. Naval nuclear-powered ships are based, overhauled, or constructed.

Discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment.

Low-level cobalt-60 radioactivity in harbor bottom sediment is detectable around a few piers at operating bases and shipyards where nuclear-powered ship maintenance and overhauls have been conducted over a period of several years. Cobalt-60 is not detectable above background levels in general harbor-bottom areas away from these piers. Maximum total radioactivity observed in a United States harbor is less than one curie of cobalt-60. Comparison to previous environmental monitoring data in references 5 through 9 shows that these environvironmental cobalt-60 levels has been steadily decreasing.

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Radiation Exposure to a Phantom Patient During Simulated Chiropractic Spinal Radiography

Jerome I. Levine,[1] *Joseph W. Howe,*[2] and *James W. Rolofson*[3]

Radiographic exposures to various organs of a simulated patient were determined for 31 techniques of spinal radiography used by doctors of chiropractic. It was determined that the radiation exposure from the most commonly used techniques would be reduced by changing to techniques using higher filtration, higher kilovoltage with reduced milliampere-seconds, and smaller beam areas. The use of split or graduated screens, step wedges, and masks also reduced radiation exposure to the simulated patient without reducing the radiographic quality of the films.

National and international organizations interested in the health and safety of the public have increasingly emphasized the need to reduce unnecessary exposure from ionizing radiation. The Federal Radiation Council (FRC) has adopted the conservative hypothesis that any exposure may have a resultant biological effect; therefore, it is axiomatic that unnecessary exposure to radiation should be avoided.

The primary goal in roentgenology is to obtain the maximum useful information with the minimum radiation exposure to patient and operating personnel consistent with the clinical objectives of the examination. Assessment of patient exposures to radiation resulting from various techniques used in chiropractic roentgenology will aid the individual chiropractor in his selection of those methods which will permit optimum diagnostic quality with minimum patient exposure.

Numerous studies have been conducted to measure the exposure to x rays resulting from various techniques commonly employed in medical diagnostic radiology (*1–7*). However, none of these studies has included the techniques employed by doctors of chiropractic.

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The purpose of this study was to determine: (1) the x-ray exposure to patients at selected body and organ sites resulting from various x-ray examinations performed by the chiropractors, and (2) the possible reduction of patient exposure with the use of diverse types of x-ray accessories available to the profession.

Methods and materials

The study was performed by taking spinal radiographs of a phantom with thermoluminescent dosimeters placed at preselected sites upon the surface and within the phantom. During each of the techniques simulated, the dosimeters measured the exposure at the incident skin surface, surface of the eye, and the exit surface of the skin, and the exposure to the male and female gonads and the thyroid gland. Also evaluated were several types of x-ray beam collimators and the effect of varying total filtration in the useful beam.

For the purpose of determining the x-ray exposure, the patient was simulated by a Machlett-Alderson phantom described as an "average-size, anatomically correct man, molded of tissue-equivalent materials on a natural human skeleton" (*8*). The phantom, in addition to limited neck motion, provides universal motion at the shoulders, flexion at elbows, extension at knees, and flexion, extension, and limited abduction at the hips (*9*). In order that all radio-

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graphic films might be exposed with the phantom in an upright position, a support stand was constructed from ⅜ inch (1 cm) plywood and the phantom placed astride the stand allowing for close proximity to the upright bucky.

Radiation exposure measurements during this study were made with lithium fluoride (LiF) powder, TLD-100[4], encapsulated in gelatin capsules. Such capsules were easily inserted into the thyroid, ovary, etc. sites of the phantom and were coded as to their site location and the exposure technique employed. Before any exposure measurements were made, a calibration of the LiF powder's sensitivity was determined throughout the energy range of interest (60 to 100 kVp).

A full-wave rectified x-ray machine capable of operation at 150 kVp and 500 mA was used as the x-ray source throughout the study. Prior to use, the machine was calibrated to accurately determine the peak kilovoltage delivered at the kV control settings. Two independent methods were used for calibration work. In the first method, a high precision resistance bank of known value was used. Measurements were repeated at 3 kV steps throughout the range of interest to obtain a calibration curve of measured kilovoltage versus indicated machine kilovoltage. The second calibration procedure, a K-edge technique described by Greening (*10*), was employed to verify the accuracy of the first calibration. Agreement for the curves was found to be within ± 3 percent for the two methods.

The x-ray tubehead was mounted with the long axis of the tube aligned parallel to the long axis of the spine. The cathode portion of the beam was directed toward the anatomic area of greatest density (i.e., the lumbar region) to take possible advantage of any "heel effect" (*11*). An upright wall-mounted 14-by 36-inch (36 by 91 cm) bucky diaphragm,[5] which incorporated a 5:1 ratio linear grid with variable speed travel, was used for all exposures throughout the study.

X-ray beam collimation for the various diagnostic radiographic field sizes needed was accomplished by the use of several types of collimators. One type offered continuous field-size adjustment with light definition of the field, making alignment and collimation exceedingly simple. This collimator incorporated an equivalent inherent filtration of approximately 3.5 mm of aluminum. Another type of collimator employed a circular indicator disc offering a selection of fixed radiographic fields corresponding to standard cassette sizes. Rotating of the disc permitted the operator to select the desired field size and obtain that coverage at a specified target-to-film distance. The dial field collimator model had a small light source for locating the central ray and alignment of the bucky tray.

An additional device, designed for full-spine radiographs, was tested on a single 14-by 36-inch (36 by 91 cm) film. This apparatus, known as the "swinging diaphragm," is attached to the tubehead and supported by its own adjustable metal legs. A spring-suspended diaphragm having separately adjustable openings for the three spinal regions is moved crosswise in front of a fixed port opening thus allowing more than one individual exposure of the spine to be made on the same film. A step-type filtration system was incorporated with the hinged covering of the port nearest the patient. The aluminum filter thicknesses were 3.51 mm for the lumbar region, 2.65 mm for the thoracic region, and 1.04 mm for the cervical region. This unit is not currently available for purchase in this country.

The following general procedure was used in obtaining the exposure measurements and exposing the films during this study. A collimator was mounted on the tubehead and the proper target-to-film distance for the diagnostic examination was selected. Proper field size selection was made, and any necessary alignments in equipment and phantom were verified. A loaded cassette was placed in the bucky tray and a correct speed setting made for grid movement. TLD capsules were placed on the phantom by means of double-sided cellophane tape at the location of the central ray entrance and exit beam, lens of the eyes, and male gonads. Dosimeter capsules were inserted into the phantom at the left and right thyroid locations and the female ovary sites.

DuPont Par Speed and Hi Speed combination intensifying screens mounted within magnesium-front, 14-by 36-inch (36 by 91 cm) cassettes were

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[4] Harshaw Chemical Co., Solid State Crystal Dept., 1945 East 97th St., Cleveland, Ohio.

[5] Universal Bucky Diaphragm Model 3650–YE, Serial No. 18705, Universal X-ray Products, Inc., Chicago, Ill.

used in combination with DuPont Cronex II radiographic film.

Operating parameters and other conditions for the common techniques as well as the higher kVp techniques were provided by Dr. J. W. Howe.[6]

Exposed films were hand processed in a Bar-Ray sensitometric processing unit containing fresh Kodak liquid x-ray developers with nitrogen burst agitation. The films were developed for 5 minutes at a temperature of 68° ± 0.1°F. After 20 seconds in the stop solution, the films were placed in Kodak liquid fixer for 10 minutes, washed for 30 minutes and dried in a warm air stream. Films were identified upon development by coded numbers.

TLD capsules were read out and the exposure values in roentgens were recorded on data sheets corresponding to the diagnostic techniques and dosimeter sites.

Data and results

The exposure measurements obtained for all techniques tested are summarized in tables 1 through 3.

Table 1 presents the technical factors for each full spine AP examination used along with the corresponding exposure measurements obtained. The technical factors chosen for use with the swinging diaphragm unit in techniques 1 through 3 were suggested by Winterstein.[7] In comparing techniques 1 and 2 for the swinging diaphragm unit, it can be easily seen that technique 2 resulted in a reduction in exposure to all sites by approximately a factor of two. All factors were constant for the two methods with the single exception of increased filtration in technique 2. The final method used with the swinging diaphragm was a high kVp and reduced mAs technique which again showed significant patient exposure reduction in comparison with techniques 1 and 2.

The remaining methods listed in table 1 show the exposure values resulting from various combinations of kVp, mAs, filtration, intensifying screens and types of collimators. The lowest overall exposure values measured for a single type intensifying screen resulted from the use of the adjustable rectangular field collimator, increased filtration, and the high kVp as shown in technique number 9. Likewise, the split screen method utilizing Par Speed screens for the upper two-fifths of the film and Hi Speed screens for the lower three-fifths of the film showed the lower exposure values when the high kVp technique was used in conjunction with the same collimator and increased filtration (technique number 11).

In table 2, data are presented for AP lumbar and thoracic region film techniques. An examination of techniques 16 through 19 reveals that the high kVp method again is superior in reducing patient exposure at all locations in comparison with the "common" technique, although the eye exposures for techniques 18 and 19 were very similar.

The thoracic techniques established method 23 as the one offering the greatest reduction in patient exposure in comparison to the others described. Using the adjustable field-size collimator to narrow the field width from 14 to 8 inches (36 to 20 cm) offered a distinct reduction in exposure readings while still presenting the entire spinal column on the radiograph for diagnosis. By decreasing field size, scattered radiation to the film is theoretically reduced, which should benefit detail as well as reduce patient exposure.

From table 3 it can be established that, from the viewpoint of reduced patient exposure, technique 26 for an AP cervical spine examination is superior to the other methods described. The increased values noted in the average eye lens exposure in techniques 29 through 31 are believed to be caused by failure of the collimator used in these exposures to limit the field size to the specific limits indicated.

Table 4 indicates a comparison of the two collimators selected with a standard device, namely a Picker radiographic collimator. The data indicate that the swinging diaphragm unit and the Dial-X collimator are not accurate.

Evaluation of film quality

Film quality and detail were judged independently by Dr. J. W. Howe and two other members

[6] Private communication from J. W. Howe, D.C. chief, Department of Roentgenology, Associates Diagnostic and Research Center, 835 Southeast Avenue, Tallmadge, Ohio 44278.

[7] Private communication from I. R. Winterstein, D.C., Department of Roentgenology, National College of Chiropractic.

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Table 1. AP full spine exposure values measured at selected phantom sites during various diagnostic radiographic techniques

Technique	Total filtration[a] (mm of Al)	Type of collimator	Screen speed	kVp	mAs	All values reported in mR					
						Entrance exposure	Exit exposure	Average thyroid exposure	Average male gonad exposure	Average female gonad exposure	Average eye exposure
1. Swinging diaphragm	[b]3.54 [c]5.15 [d]6.01		Par	90	[b]100 [c]250 [d]300	126.6 292.5 315.9	27.6 15.4 15.4	126.7	269.2	70.6	126.6
2. Swinging diaphragm	[b]4.57 [c]6.18 [d]7.04		Par	90	[d]100 [c]250 [b]300	68.2 189.7 199.1	12.1 8.4 8.4	69.4	181.6	45.3	64.8
3. Swinging diaphragm	[b]4.57 [c]6.18 [d]7.04		Par	110	[b]10 [c]50 [d]75	13.9 63.9 78.3	1.7 3.3 5.0	16.9	85.3	26.6	8.9
4. Common[e] (one screen)	[f]4.52 [g]8.23	Dial-X[h,i]	Hi	80	200	240.4	9.8	133.8	67.1	23.8	84.9
5. High kVp (one screen)	[f]4.52 [g]8.23	Dial-X	Hi	100	60	108.8	4.6	69.4	47.2	15.5	43.1
6. High kVp (one screen)	4.52	Dial-X	Hi	100	60	129.4	3.6	70.4	104.9	30.9	45.4
7. Common[e] (one screen)	4.52	Dial-X	Hi	80	200	242.7	8.4	137.2	193.8	43.6	86.0
8. Common[e] (one screen)	7.02	Picker[k]	Hi	80	200	216.0	7.1	126.6	16.9	36.5	8.5
9. High kVp (one screen)	7.02	Picker	Hi	100	60	126.8	2.6	70.0	10.6	25.3	2.3
10. Common[e] (split screen)	7.02	Picker	Combined[m]	95	250	480.9	20.1	281.2	41.7	104.7	21.9
11. High kVp (split screen)	7.02	Picker	[m]	100	75	111.3	3.6	68.8	8.3	25.3	3.4
12. Common[e] (split screen)	[f]4.52 [g]8.23	Dial-X[j]	[m]	95	250	353.4	14.7	268.9	82.6	54.0	167.2
13. High kVp (split screen)	[f]4.52 [g]8.23	Dial-X[j]	[m]	100	75	116.5	6.7	99.7	27.1	18.1	55.2
14. High kVp (split screen)	4.52	Dial-X[j]	[m]	100	75	176.8	10.8	105.9	153.6	44.1	63.9
15. Common[e] (split screen)	4.52	Dial-X[j]	[m]	95	250	484.3	26.0	299.3	440.2	115.5	176.7

[a] Includes 1 mm aluminum equivalent filtration from x-ray tube.
[b] Cervical.
[c] Thoracic.
[d] Lumbar.
[e] Technique used by the majority of chiropractors as determined by Dr. J. W. Howe.
[f] Upper 1/3 of beam.
[g] Lower 2/3 of beam.
[h] Dial-X Collimator Model DM; Dial-X Instruments, Inc., 331 W. Merrick Road, Valley Stream, N.Y. (Serial No. 3133).
[i] 14- by 36-inch (36 by 91 cm) field. Field size as listed by manufacturer.
[k] Picker Radiographic Collimator; Delux Model 2089, Picker X-ray Company, White Plains, N.Y.
[m] Upper 2/5's of screen—Par; lower 3/5's of screen—Hi.

Table 2. AP regional spine exposure values measured at selected phantom sites during various diagnostic radiographic techniques

Technique	Total filtration[a] (mm of Al)	Type of collimator	Screen speed	kVp	mAs	Field size (inches)[b]	All values reported in mR					
							Entrance exposure	Exit exposure	Average thyroid exposure	Average male gonad exposure	Average female gonad exposure	Average eye exposure
16. Common[c] lumbar	4.52	Dial-X[d]	Par	85	100	14 by 17	745.7	21.5	9.2	36.8	133.8	5.7
17. High kVp lumbar	4.52	Dial-X	Par	110	10	14 by 17	132.2	6.7	2.0	9.5	32.2	1.4
18. High kVp lumbar	7.02	Picker[e]	Par	110	10	14 by 17	166.1	4.4	.8	3.5	30.3	.6
19. Common[c] lumbar	7.02	Picker	Par	85	100	11 by 14	844.3	16.0	2.3	6.4	104.6	.5
20. Common[c] thoracic	4.52	Dial-X	Par	75	50	14 by 17	176.2	4.5	26.7	1.8	5.4	2.7
21. DuPont thoracic (*12*)	4.52	Dial-X	Par	90	100	14 by 17	837.9	32.7	137.0	11.5	33.9	11.9
22. High kVp thoracic	4.52	Dial-X	Par	100	15	14 by 17	171.6	[f]	30.5	2.0	7.8	2.3
23. High kVp thoracic	7.02	Picker	Par	100	15	8 by 17 field (14 by 17 film)	184.5	4.1	3.4	ND	2.5	ND
24. DuPont thoracic (*12*)	7.02	Picker	Par	90	100	8 by 17 field (14 by 17 film)	882.7	21.5	19.9	3.9	12.4	4.0
25. Common[c] thoracic	7.02	Picker	Par	75	50	8 by 17 field (14 by 17 film)	201.3	4.5	4.5	1.7	3.3	1.7

[a] Includes 1 mm aluminum equivalent filtration from x-ray tube.
[b] 14 by 17 inches = 36 by 43 cm; 11 by 14 inches = 28 by 36 cm; 8 by 17 inches = 20 by 43 cm. Field size as listed by manufacturer.
[c] Technique used by the majority of chiropractors as determined by Dr. J. W. Howe.
[d] Dial-X Collimator Model DM; Dial-X Instruments, Inc., 331 W. Merrick Road, Valley Stream, N.Y. (Serial No. 3133).
[e] Picker Radiographic Collimator; Delux Model 2089, Picker X-ray Company, White Plains, N.Y.
[f] Measurement unavailable—capsule came open and powder lost during study.
ND, nondetectable.

Table 3. AP cervical spine exposure values measured at selected phantom sites during various diagnostic radiographic techniques

Technique	Total filtration[a] (mm of Al)	Type of collimator	Screen speed	kVp	mAs	Field size (inches)[b]	All values reported in mR					
							Entrance exposure	Exit exposure	Average thyroid exposure	Average male gonad exposure	Average female gonad exposure	Average eye exposure
26. High kVp cervical	7.02	Picker	Par	84	10	8 by 10	57.3	4.5	45.7	ND	ND	4.2
27. DuPont cervical (*12*)	7.02	Picker	Par	70	40	8 by 10	137.6	7.7	102.5	0.5	ND	8.2
28. Common[c] cervical	7.02	Picker	Par	60	50	8 by 10	103.9	4.3	74.4	ND	0.3	5.7
29. High kVp cervical	4.52	Dial-X	Par	84	10	8 by 10	58.3	4.2	45.9	ND	.7	[d]47.5
30. DuPont cervical (*12*)	4.52	Dial-X	Par	70	40	8 by 10	139.8	6.8	103.2	ND	.4	[d]119.5
31. Common[c] cervical	4.52	Dial-X	Par	60	50	8 by 10	100.0	5.5	71.5	.4	.2	[d]85.3

[a] Includes 1 mm aluminum equivalent filtration from x-ray tube.
[b] 8 by 10 inches = 20 by 25 cm. Field size as listed by manufacturer.
[c] Technique used by the majority of chiropractors as determined by Dr. J. W. Howe.
[d] These high readings of average exposure to lens of eye must be due to the oversized field of the Dial-X collimator (see table 4). Entrance beam was aligned at same place on the phantom for each collimator. Evidently, the Picker collimator is much more exact in defining field size.
ND, nondetectable.

Table 4. Field size for various types of x-ray collimators

Collimator or beam-limiting device	Field size as listed by manufacturer (inches)	Target to film distance for listed field size (inches)	Field size measured (Polaroid film) (inches)	Target to film distance for measured field size (inches)	Excess beam area (inches²)	Percent error[a]
1. Swinging diaphragm unit	None listed by manufacturer—unit designed for use in full spine radiographs, i.e., 14 by 36 film (36 by 91 cm)	96 (244 cm)	24 by 51.5 (61 by 131 cm)	96 (244 cm)	732 (4,740 cm²)	145
2. Dial-X collimator	14 by 36 (36 by 91 cm)	60 (152 cm)	17.5 by 38 (44.5 by 97 cm)	60 (152 cm)	161 (1,040 cm²)	32
	14 by 36 (36 by 91 cm)		21.5 by 45.25 (54.7 by 115 cm)	72 (183 cm)	469 (3,030 cm²)	93
	14 by 17 (36 by 43 cm)	36 (91 cm)	17.25 by 19.75 (44 by 50 cm)	36 (91 cm)	103 (665 cm²)	43
	14 by 17 (36 by 43 cm)		19.5 by 22.25 (49.6 by 56.6 cm)	40 (102 cm)	196 (1,270 cm²)	82
	8 by 10 (20 by 25 cm)	36 (91 cm)	9.5 by 12 (24.2 by 30.5 cm)	36 (91 cm)	34 (220 cm²)	43
	8 by 10 (20 by 25 cm)		10.75 by 13.75 (27.3 by 35 cm)	40 (102 cm)	67.8 (438 cm²)	85
3. Picker radiographic collimator	14 by 17 (36 by 43 cm)	72 (183 cm)	13.8 by 17.1 (35 by 43 cm)	72 (183 cm)	−2.02 (−13 cm²)	−.01
	8 by 17 (20 by 43 cm)		8 by 17.1 (20 by 43 cm)		.8 (5 cm²)	.01

[a] Excess beam area to standard beam area (area of field size as listed by manufacturer).

of the chiropractic profession. The phantom offered inherent problems which affected film quality since the jointed arrangement that allowed limited mobility of the neck offered far different radiopacity than the surrounding tissues, and the mediastinal area was considerably different in its characteristics than what would be encountered in the human body. Other differences in the phantom as compared to a human subject make the films produced in this study less than optimum so that estimates regarding quality and detail could only be considered roughly equivalent to those which would be present on radiographic films of the human subject. A further limitation, the use of a 5:1 ratio in the bucky grid, made film quality less than optimum. The American College of Chiropractic Roentgenologists has long recommended a minimum of 8:1 grid ratio for spinal radiography.

With these factors considered, judgment of film quality and detail showed the best full spine radiographs to have been produced by techniques 2, 11, and 13; with 9 and 4 next best; 1, 5, 6, 7, 8, and 14 were judged acceptable; while 3 was not sufficiently dense to be of diagnostic value; and techniques 10, 12, and 15 produced radiographs which were entirely too dense for evaluation.

In none of the full spine films was the cervical

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region adequately portrayed due to the variation in radiopacity inherent in the phantom. The best cervical visualizations were in techniques 2, 11, and 13. The regional films of the cervical area were also of poor quality and were generally comparable to the full spine studies of the cervical region in detail. Film quality and detail were not remarkably enhanced in the regional films of the thoracic or lumbar areas as compared to the same areas viewed on the full spine radiographs. There was some improvement in detail in the films where collimation limited the exposed area to a smaller field than the film size.

The use of split screens as compared to a uniform speed screen did seem to enhance film quality sufficiently to make their use worthwhile. The abrupt change from slow screen to fast was objectionable. There are now available "proportioned" or "graduated" screens which increase in speed from one end to the other without the sharp change seen in the split screens. These were not employed in this study, but would seem preferable to the abrupt transition of the split screen.

Step wedges were employed in techniques 4, 5, 12, and 13. These did help slightly to enhance radiographic quality, but the difference between techniques 2, 11, and 13 was not really significant. Technique 2 employed the swinging diaphragm with uniform par speed screens and moderately high kVp. Technique 11 employed the variable collimator with split screens, extra filtration, and high kilovoltage. Technique 13 utilized the Dial-X collimator with step wedges, split screens, and high kilovoltage. The practical difference in film quality among the three was negligible. The ability to select the proper technique for each region with the swinging diaphragm made this equivalent to the split screen and step wedge combination.

We can conclude from judgment of film quality that with certain reservations, a properly exposed 14-by 36-inch (36 by 91 cm) film utilizing a 72 inch (183 cm) or greater target-to-film distance (TFD) will give roughly as good film quality as will regional films of any spinal regions. The factor of radiographic distortion, though, makes regional films more valuable for specific information regarding a particular area, although if an 84 inch (210 cm) or greater TFD is used, the angle of incidence of the x rays is equal to or less than the angle of incidence used for a 14- by 17-inch (36 by 43 cm) film at a 40 inch (100 cm) TFD.

Taking technique 2 for a basis and comparing it with techniques 18, 23, and 26 for regional AP films of cervical, lumbar and thoracic areas, we see that there is only slightly less of an entrance exposure for the regional films than for the full spine, while the thyroid dose is lower combining techniques 18, 23, and 26 than in techniques 2, 11, or 13.

The exposure to the male gonads for techniques 18, 23, and 26 totals 3.5 mR which compares favorably with the 8.3 mR seen in technique 11. The fact that there is a much higher male gonadal exposure in techniques 2 and 13 indicates that collimation was not as sharp under these two techniques as by use of a variable collimator. The female gonadal exposure by combining techniques 18, 23, and 26 totals 32.8 mR, which is higher than was seen in techniques 11 or 13 and lower than that seen in technique 2. The eye exposure from combining techniques 18, 23, and 26 totals 4.8 mR which again is slightly more that was present in technique 11, with the greater differences in techniques 2 and 13 again reflecting the less adequate collimation employed. From these findings we can conclude that there is not appreciably more radiation to selected organ sites of the patients in a full spine film using high kilovoltage, low milliamperage techniques and adequate collimation and filtration than would be present from AP regional films using a similar high kVp, low mA, diagnostic radiographic procedure.

Conclusions

It is clear that some of the commonly used techniques, such as those used in this study and in reference (*12*), do give excess radiation factors as well as excessive film density which yields less than optimum film quality. There is a considerable need for further studies and efforts toward obtaining optimum quality radiographs with less patient exposure. Considering the radiation exposure of the various critical areas, film quality, and detail available, it is conclusive that diagnostic quality does not suffer as compared to techniques in common usage through utilizing

those technical factors which produce the least patient exposure. Sharp collimation, high filtration, and use of split or graduated screens where applicable are surely of great value. If a step wedge arrangement could be attached to a variable collimator, and masks or similar devices used to further restrict the beam from areas where there is no clinical interest, there would unquestionably be further enhancement of radiographic quality and a further decrease in radiation exposure to the patient.

Summary

The data presented in this study show that patient exposures received during diagnostic spinal examinations can vary significantly depending on the radiographic technique used.

The study indicates that increasing the amount of filtration, using an adjustable rectangular collimator with a beam-defining light, and raising the voltage coupled with an appropriate reduction in amperage-time are extremely helpful in reducing patient x-ray exposure. Collimating the beam to the smallest possible dimension that encompasses the spinal column will also reduce exposure to the patient.

Acknowledgement

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SECTION I. MILK AND FOOD

Milk Surveillance, January 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State Health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

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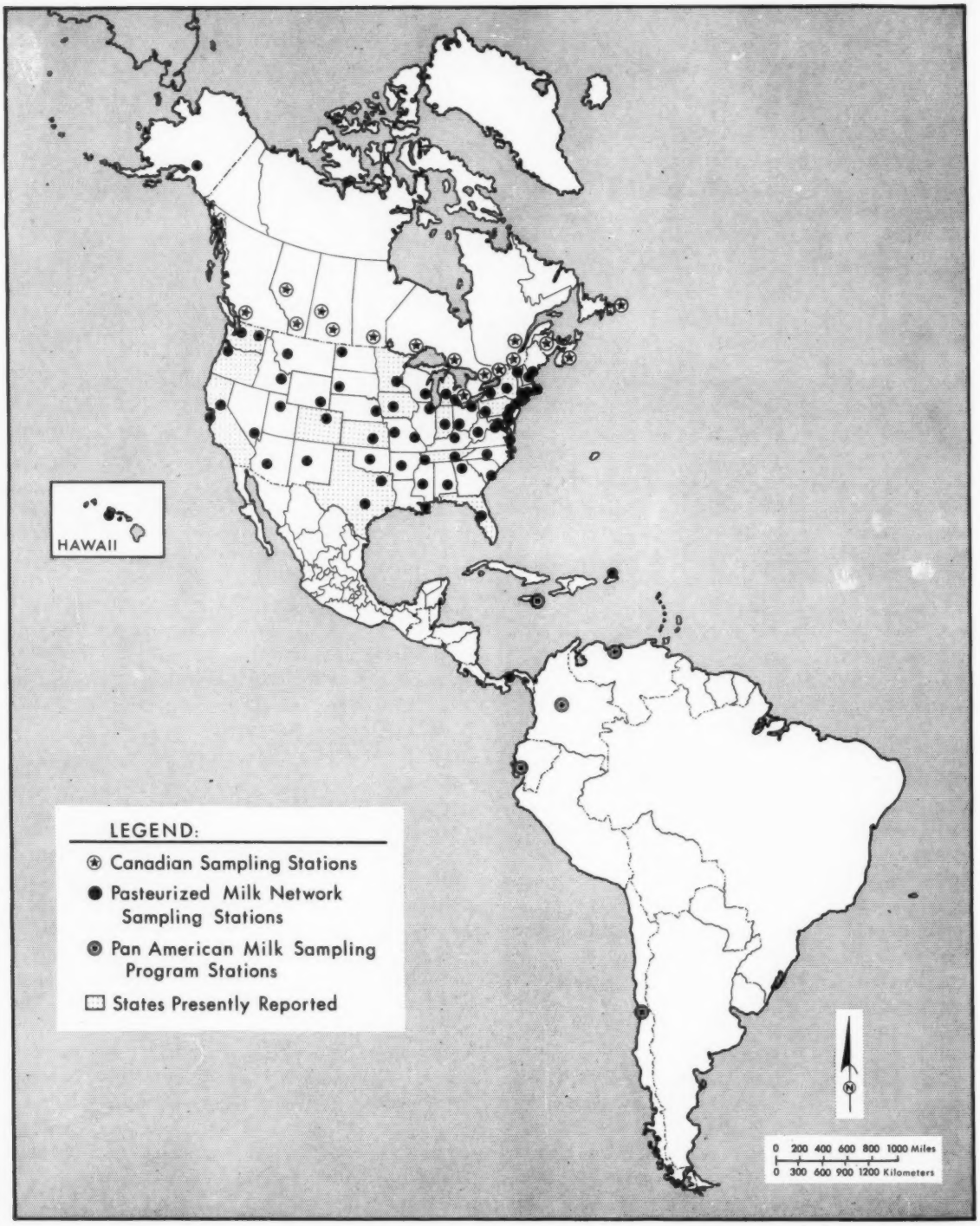

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 20 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic procedures. The methods used by each of the networks have been

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category			
	Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium 89: High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90: Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131: High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137: High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140: High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration less than or equal to 2σ of the known concentration.
[b] Measured concentration greater than 2σ and less than or equal to 3σ of the known concentration.
[c] Measured concentration greater than 3σ of the known concentration.

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referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation (table 2) also reflects whether raw or pasteurized milk was collected. An analysis of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that, for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Table 2. Concentration of radionuclides in milk for January 1971 and 12-month period, February 1970 through January 1971

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	4	6	0	0	13	8
Alaska:	Palmer[c]	P	3	6	0	0	16	10
Ariz:	Phoenix[c]	P	0	1	0	0	0	0
Ark:	Little Rock[c]	P	14	13	0	0	0	13
Calif:	Sacramento[c]	P	0	2	0	0	0	0
	San Francisco[c]	P	0	2	0	0	0	0
	Del Norte	P	16	17	0	0	10	14
	Fresno	P	2	2	0	0	0	1
	Humboldt	P	5	5	0	0	2	5
	Los Angeles	P	3	2	0	0	0	0
	Mendocino	P	5	3	0	0	4	2
	Sacramento	P	3	3	0	0	3	1
	San Diego	P	2	2	0	0	0	0
	Santa Clara	P	2	2	0	0	0	1
	Shasta	P	2	3	0	0	3	2
	Sonoma	P	3	3	0	0	1	1
Colo:	Denver[c]	P	3 (2)	5	0 (2)	0	11 (2)	1
	West	R	(d)		NS	*1	NS	*4
	Northeast	R	(d)		*0 (5)	*0	*0 (5)	*0
	East	R	(d)		*0 (2)	*0	*0 (2)	*0
	Southeast	R	(d)		NS	*0	NS	*0
	South Central	R	(d)		NS	NS	NS	NS
	Southwest	R	(d)		*0	*0	*0	*4
	Northwest	R	(d)		NS	*5	NS	*0
Conn:	Hartford[c]	P	8	7	0	0	17	12
	Central	P	7	7	0	0	23	16
Del:	Wilmington[c]	P	8	9	0	0	13	8
D.C:	Washington[c]	P	7	7	0	0	0	7
Fla:	Tampa[c]	P	5	5	0	0	40	50
	West	R	6	6	0	0	24	48
	North	R	4	10	0	0	12	26
	Northeast	R	7	6	0	0	21	39
	Central	R	NS	7	0	1	24	48
	Tampa Bay area	R	7	6	0	0	39	50
	Southeast	R	11	9	0	0	74	76
Ga:	Atlanta[c]	P	11	11	0	0	16	14
Hawaii:	Honolulu[c]	P	4	2	0	0	0	0
Idaho:	Idaho Falls[c]	P	4	5	0	0	17	7
Ill:	Chicago[c]	P	7	7	0	0	0	10
Ind:	Indianapolis[c]	P	6	8	0	0	12	6
	Northeast	P	8	10	0	0	10	12
	Southeast	P	10	11	0	0	15	12
	Central	P	8	9	0	5	10	10
	Southwest	P	13	12	0	0	10	10
	Northwest	P	10	11	0	0	10	12
Iowa:	Des Moines[c]	P	5	6	0	0	12	3
	Iowa City	P	8	8	0	0	19	14
	Des Moines	P	7	8	0 (4)	0	13 (4)	9
	Spencer	P	4	5	0	0	12	8
	Fredericksburg	P	NS	NS	NS	NS	NS	NS
Kans:	Wichita[c]	P	7	8	0	0	0	3
	Coffeyville	P	8	9	0	2	0	2
	Dodge City	P	5	7	0	0	0	1
	Falls City	R	11	14	0	3	12	6
	Hays	P	12	13	0	2	0	1
	Kansas City	P	9	8	0	0	12	5
	Topeka	P	9	10	0	2	21	6
	Wichita	P	10	12	0	0	11	1
Ky:	Louisville[c]	P	8	9	0	0	0	4
La:	New Orleans[c]	P	16	14	0	0	26	19
Maine:	Portland[c]	P	9	10	0	0	15	22
Md:	Baltimore[c]	P	9	8	0	0	16	8
Mass:	Boston[c]	P	9	10	0	0	23	21
Mich:	Detroit[c]	P	7	8	0	0	12	9
	Grand Rapids	P	7	9	0	0	18	13
	Bay City	P	NS	7	*0	*0	14	11
	Charlevoix	P	11	12	*0 (2)	*1	7 (2)	15
	Detroit	P	6	8	*0	*0	12	8
	Grand Rapids	P	8	9	*0	*0	0	7
	Lansing	P	8	9	*0 (2)	*0	15 (2)	14
	Marquette	P	13	14	*0 (2)	*0	21 (2)	23
	Monroe	P	5	6	*0 (2)	*0	0 (2)	3
	South Haven	R	8	8	*0 (3)	*0	4 (3)	6
Minn:	Minneapolis[c]	P	9	9	0	0	11	11
	Bemidji	P	8	8	0	0	21	20
	Mankato	P	5	4	0	0	0	0
	Rochester	P	6	6	0	0	0	11
	Duluth	P	11	13	0	0	22	27
	Worthington	P	6	4	0	0	0	0

See footnotes at end of table.

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Table 2. Concentration of radionuclides in milk for January 1971 and 12-month period, February 1970 through January 1971—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
Minn:	Minneapolis	P	20	10	0	0	17	16
	Fergus Falls	P	6	5	0	0	11	13
	Little Falls	P	9	11	0	0	0	34
Miss:	Jackson[c]	P	9	11	0	0	0	11
Mo:	Kansas City[c]	P	6	8	0	0	0	2
	St. Louis[c]	P	7	8	0	0	12	5
Mont:	Helena[c]	P	4	5	0	0	14	8
Nebr:	Omaha[c]	P	NA	5	0	0	0	1
Nev:	Las Vegas[c]	P	0	2	0	0	0	0
N.H:	Manchester[c]	P	9	9	0	0	22	20
N.J:	Trenton[c]	P	7	7	0	0	15	10
N.Mex:	Albuquerque[c]	P	3	3	0	0	0	0
N.Y:	Buffalo[c]	P	7	7	0	0	14	11
	New York City[c]	P	9	10	0	0	16	18
	Syracuse[c]	P	7	7	0	0	0	9
	Albany	P	11	7	0 (4)	0	21 (4)	0
	Messena	P	10	8	0 (2)	0	26 (2)	22
	Newburg	P	8	7	0 (3)	0	0 (4)	0
	New York City	P	*0	8	0	0	0	0
	Syracuse	P	6	4	0 (2)	0	0 (2)	0
N.C:	Charlotte[c]	P	10	11	0	0	14	13
N.Dak:	Minot[c]	P	9	10	0	0	0	11
Ohio:	Cincinnati[c]	P	8	7	0	0	12	4
	Cleveland[c]	P	7	8	0	0	12	12
Okla:	Oklahoma City[c]	P	NA	7	0	0	13	6
Oreg:	Portland[c]	P	4	6	0	0	0	5
	Baker	P	NA	4	*0	*0	0	6
	Coos Bay	P	6	6	*0	*0	0	11
	Eugene	P	2	2	*0	*0	0	3
	Medford	P	2	3	*0	*0	0	8
	Portland composite	P	3	5	*0	*0	0	7
	Portland local	P	4	5	*0	*0	0 (2)	6
	Redmond	P	NA	4	*0	*0	0	0
	Tillamook	R	NA	8	*0	*0	16	16
Pa:	Philadelphia[c]	P	NS	9	NS	0	NS	7
	Pittsburgh[c]	P	11	11	0	0	17	14
	Dauphin	P	7	8	11	2	17	10
	Erie	P	NS	12	NS	1	24	26
	Philadelphia	P	NS	8	NS	0	24	15
	Pittsburgh	P	8	13	0	1	18	20
S.C:	Charleston[c]	P	11	10	0	1	12	18
S.Dak:	Rapid City[c]	P	7	7	0	0	0	4
Tenn:	Chattanooga[c]	P	8	9	0	0	0	9
	Memphis[c]	P	7	9	0	0	15	7
	Chattanooga	P	8	9	0	0	17	14
	Clinton	P	9	11	0	0	12	14
	Fayetteville	P	6	6	0 (2)	0	6 (2)	10
	Knoxville	P	9	11	0	0	18	14
	Nashville	P	6	7	0 (3)	0	12 (3)	12
Tex:	Austin[c]	P	0	2	0	0	0	2
	Dallas[c]	P	4	7	0	0	0	7
	Amarillo	R	NA	5	NA	0	NA	5
	Corpus Christi	R	NA	4	NA	0	NA	0
	El Paso	R	NA	3	NA	0	NA	2
	Fort Worth	R	4	5	0	0	0	0
	Harlingen	R	NA	2	NA	0	NA	14
	Houston	R	6	6	0	0	15	0
	Lubbock	R	NA	3	NA	0	NA	0
	Midland	R	3	2	0	0	0	0
	San Antonio	R	NA	4	NA	0	NA	0
	Texarkana	R	NA	8	NA	0	NA	0
	Tyler	R	19	16	0	0	20	18
	Uvalde	R	NA	2	NA	0	NA	0
	Wichita Falls	R	NA	4	NA	0	NA	2
Utah:	Salt Lake City[c]	P	4	4	0	0	14	9
Vt:	Burlington[c]	P	6	8	0	0	14	14
Va:	Norfolk[c]	P	9	9	0	0	12	9
Wash:	Seattle[c]	P	5	6	0	0	0	3
	Spokane[c]	P	6	5	0	0	0	2
	Benton County	R	0	0	0	0	*0	2
	Franklin County	R	7	3	0	0	*0	5
	Sandpoint, Idaho	R	13	11	0	0	23	21
	Skagit County	R	6	6	0	0	15	10
W.Va:	Charleston[c]	P	4	8	0	0	13	6
Wisc:	Milwaukee[c]	P	6	6	0	0	17	12
Wyo:	Laramie[c]	P	4	5	0	0	0	1

See footnotes at end of table.

Table 2. Concentration of radionuclides in milk for January 1971 and 12-month period, February 1970 through January 1971—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA:							
Alberta: Calgary	P	NA		NA		17	17
Edmonton	P	NA		NA		24	20
British Columbia: Vancouver	P	NA		NA		16	24
Manitoba: Winnipeg	P	NA		NA		21	24
New Brunswick: Fredericton	P	NA		NA		28	24
Newfoundland: St. John's	P	NA		NA		19	34
Nova Scotia: Halifax	P	NA		NA		16	22
Ontario: Ft. William	P	NA		NA		18	15
Ottawa	P	NA		NA		28	33
Sault Ste. Marie	P	NA		NA		28	35
Toronto	P	NA		NA		11	10
Windsor	P	NA		NA		6	10
Quebec: Montreal	P	NA		NA		15	18
Quebec	P	NA		NA		28	28
Saskatchewan: Regina	P	NA		NA		14	14
Saskatoon	P	NA		NA		12	16
CENTRAL AND SOUTH AMERICA:							
Colombia: Bogota	P	0	0	0	0	0	0
Chile: Santiago	P	0	0	0	0	0	0
Ecuador: Guayaquil	P	0	0	0	0	0	0
Jamaica: Montego Bay	P	NS	5	NS	0	NS	81
Venezuela: Caracas	P	0	1	0	0	0	0
Canal Zone: Cristobal[c]	P	3	1	0	0	14	10
Puerto Rico: San Juan[c]	P	4	4	0	0	12	7
PMN Network average[f]		6	7	0	0	10	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter

Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter

Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclides concentrations for the PMN stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average

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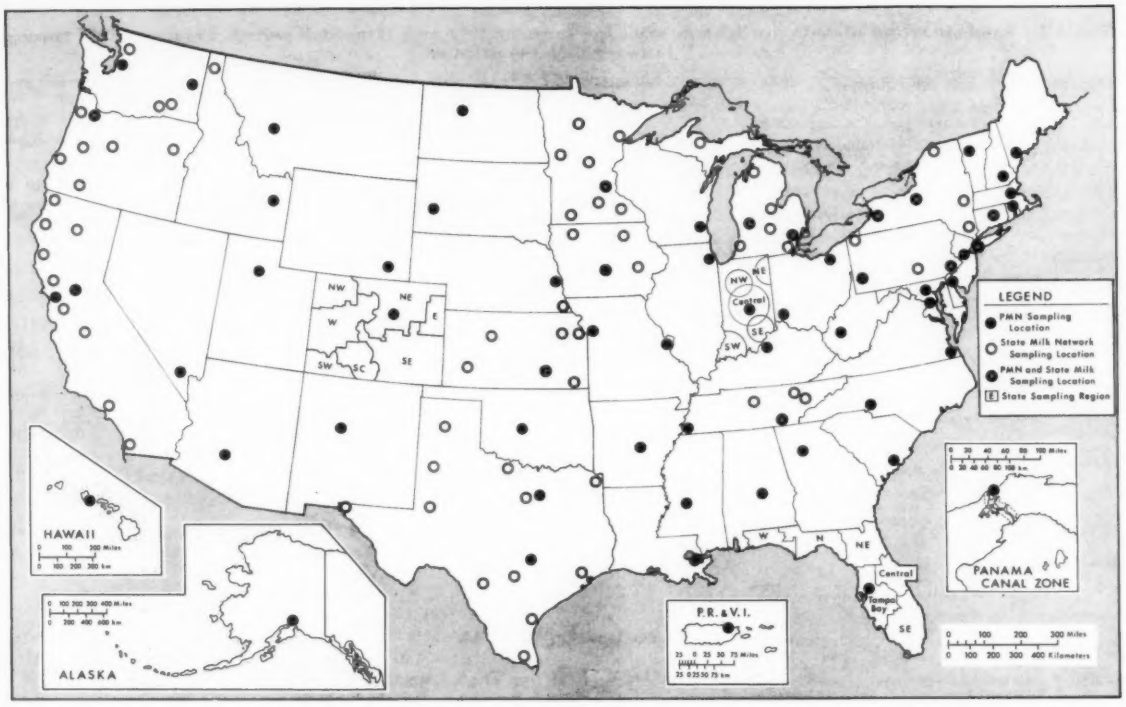

Figure 2. State and PMN milk sampling locations in the United States

for the station and in parentheses the number of samples analyzed in that month. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed populations groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for January 1971 and the 12-month period, February 1970 through January 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for January 1971 were below the respective practical reporting levels. The following station average reflects a sample in which strontium-89 was detected: Kans., Wichita (State), 6 pCi/liter; Colombia, Bogota, 5 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower guide levels established by the Federal Radiation Council, levels in milk for this radionuclide are of particu-

lar public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 20 pCi/liter in the United States for January 1971, and the highest 12-month average was 17 pCi/liter (Del Norte, Calif.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 74 pCi/liter in the United States for January 1971, and the highest 12-month average was 76 pCi/liter (Southeast Florida), representing 2.1 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level, with the exception of Dauphin, Pa.(State), 11 pCi/liter.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Nuclear Engineering
New York State Department of Environmental Conservation

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Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of
Social and Health Service

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1970	November 1970
Carbon-14 in Total Diet and Milk	July–December 1970	May 1971
Connecticut Standard Diet	July–December 1969	December 1970
Institutional Diet Samples	October–December 1970 and Annual summary 1970	May 1971
Strontium-90 in Tri-City Diets	January–December 1969	June 1970

Carbon-14 in Total Diet and Milk, July-December 1970

Office of Radiation Programs
Environmental Protection Agency

In July 1965, a program to determine the levels of carbon-14 and tritium in the total diet and milk in the United States was initiated. In December 1970, this program was transferred to the Radiation Office, (now the Office of Radiation Programs) of the Environmental Protection Agency (EPA). Initially, monthly samples from each of the EPA Institutional Total Diet Sampling Network (ITDSN) and Pasteurized Milk Network (PMN) stations were composited and analyzed according to six arbitrarily selected regions: Northeast, South, Delta, Central, Southwest, and Northwest. Figure 1 shows the ITDSN and PMN sampling stations in each of the designated regions.

In January 1966, the program was modified to include selected stations in each of the previously mentioned regions plus Alaska and Hawaii. The nine geographically distributed sampling stations are: Palmer, Alaska; Honolulu, Hawaii; Idaho Falls, Idaho; Chicago, Ill; New Orleans, La; Boston, Mass; Portland, Oreg; and Charleston, S.C. Los Angeles, Calif. is not a PMN station, but a special milk sample is collected for purposes of comparison with the routine ITDSN sample.

A 1-liter milk sample and a 2-kilogram food sample are sent to the Public Health Service's Northeastern Radiological Health Laboratory for analysis. The milk and total diet samples analyzed represent the samples collected for that month.

The carbon-14 analyses are performed semiannually. The tritium analyses were discontinued in July 1969 because the results were only slightly above the limit of detectability and were less

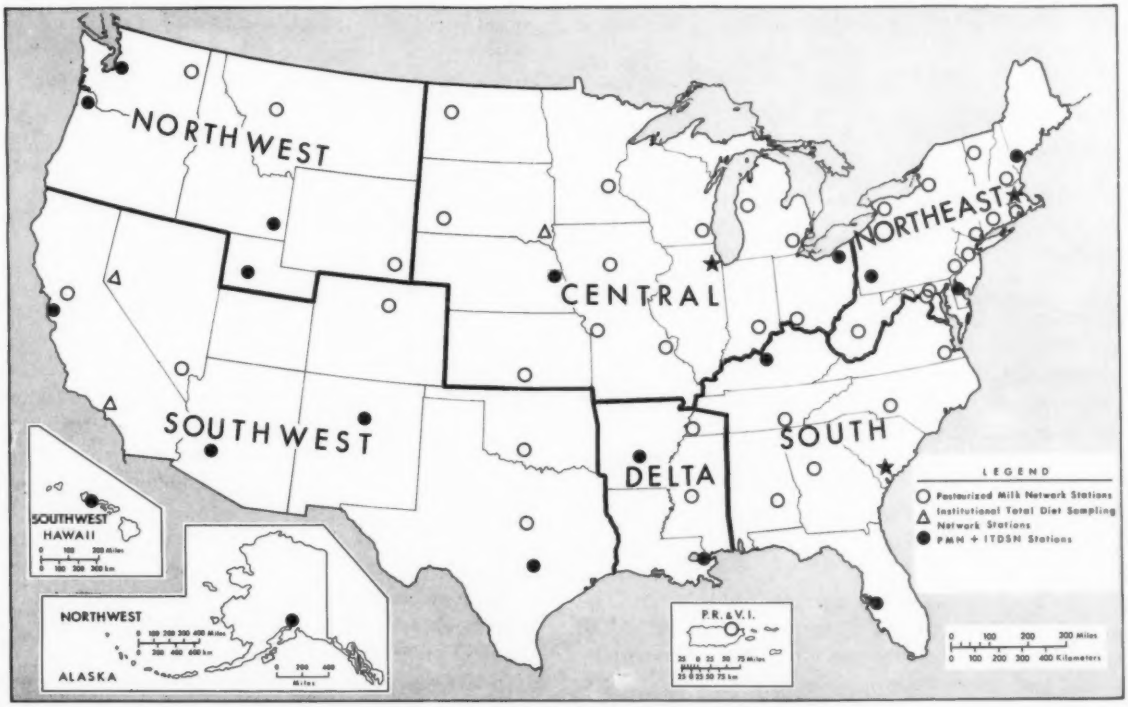

Figure 1. ITDSN and PMN sampling stations

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than 1 percent of the maximum permissible concentration for milk and food consumed by the general population.

Analytical procedures

The carbon-14 content is determined by combustion of the milk or food sample and collection and purification of the evolved carbon dioxide. The carbon dioxide is then converted to methane and counted in a gas-proportional counter (*1*).

Results and discussion

The carbon-14 concentration in food and milk was measured as dpm of carbon-14 per gram of carbon and converted to pCi/kg by using the percent carbon in the sample. The carbon content in food ranged from 9.9 to 11.0 percent with an average of 10.3 percent, and the carbon content in milk ranged from 4.9 to 6.5 percent with an average of 5.5 percent.

Table 1 shows the carbon-14 concentrations in total diet and milk for July–December 1970. The total diet average of 820 pCi/kg is lower than the average of 890 pCi/kg for the first half of 1970. The milk average of 430 pCi/kg is also lower than the average of 470 pCi/kg for the first half of 1970. The data show a gradual downward trend since 1965.

Table 1. Carbon-14 in total diet and milk July–December 1970

Location	Date collected (1970)	Concentration (pCi/kg ±2σ)	
		Total diet	Milk
Alaska: Palmer	October	790±13	400± 9
Calif: Los Angeles	November	830±13	
	October		420± 8
Hawaii: Honolulu	NS	NS	NS
Idaho: Idaho Falls	October	860±13	410±10
Ill: Chicago	October	NS	450± 8
La: New Orleans	October	820±13	440±10
Mass: Boston	October	780±15	430± 8
Oreg: Portland	October	840±13	420± 9
S.C: Charleston	October	790±13	470± 8
Average		820	430

NS, no sample.

REFERENCE

(*1*) DROBINSKI, J. C. JR., D. P. LAGATTA, A. S. GOLDIN, and J. G. TERRILL. Analyses of environmental samples for carbon-14 and tritium. Health Phys 11:385–395 (May 1965).

Other coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1965—December 1968	November 1969
January 1969—June 1970	January 1971

Radionuclides in Institutional Diet Samples, October-December 1970 and Annual Summary 1970

Environmental Protection Agency and *Food and Drug Administration*

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service (PHS) initiated its Institutional Diet Sampling Program in 1961. The program is administered by the Office of Radiation Programs, EPA, with the assistance of the Bureau of Food Sanitation, Food and Drug Administration (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. At the present time 25 institutions, distributed geographically as shown in figure 1, are being sampled. The station at Columbia, Miss., was discontinued because of cessation of the Atomic Energy Commission's testing activities at Hattiesburg, Miss. Previous results showed that the daily dietary intake of teenage girls and children from 9 to 12 years of age were comparable, while teenage boys con-

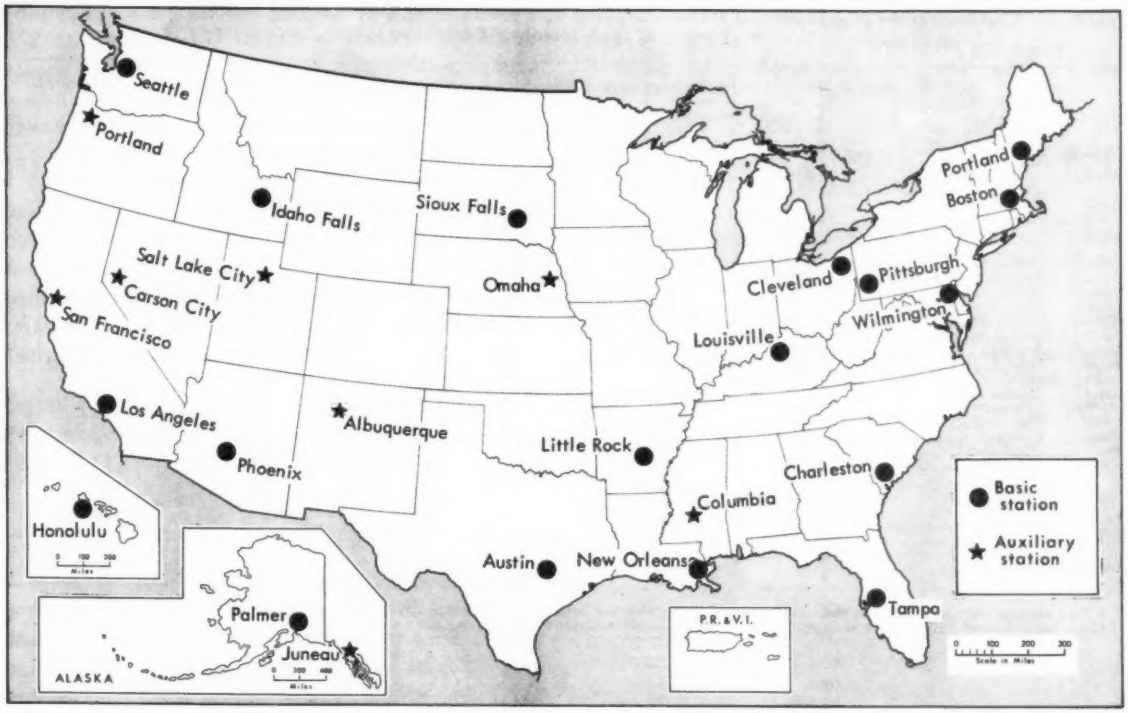

Figure 1. Institutional diet sampling locations as of December 1970

sumed 20 percent more food per day (*1*, *2*). Consequently, estimates for teenage boys and/or girls can be calculated on the basis of the dietary intake of children.

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Drinking water, not included in the samples, is also sampled periodically. Each daily sample is kept frozen until the end of the collection period and is then packed in dry ice and shipped by air express to either the Western Environmental Radiation Laboratory, Las Vegas, Nev; the Eastern Environmental Radiation Laboratory, Montgomery, Ala; or the PHS Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and analytical procedures was presented earlier (*3*).

Results

Table 1 presents the analytical results for institutional diet samples collected from all stations during October through December 1970. The data for the basic and auxiliary stations have been combined into one table since the levels of radioactivity and intake are similar. The stable elements, calcium and potassium, are reported in g/kg of diet. The radionuclide concentrations of these samples, reported in pCi/kg of diet, are corrected for radioactive decay to the midpoint of the sample collection period, where applicable. Dietary intakes in g/day or pCi/day were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.82 kg/day compared to the network average of 1.87 kg/day observed from 1961 through 1969.

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Table 1. Concentration and intake of stable elements and radionuclides in institutional total diets of children (9–12 years of age), October–December 1970

Location of institution		Month (1970)	Total weight (kg/day)	Calcium		Potassium		Strontium-90		Cesium-137	
				(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska:	Juneau	Oct.	1.57	0.6	0.9	1.8	2.8	4	6	19	30
	Palmer	Oct.	1.30	.9	1.1	1.8	2.3	7	9	11	14
Ariz:	Phoenix	Oct.	1.75	.5	.9	1.3	2.4	3	6	0	0
Ark:	Little Rock	Oct.	1.18	.8	.9	1.6	1.9	12	14	0	0
Calif:	Los Angeles	Nov.[a]	1.37	.5	.7	1.3	1.8	3	5	0	0
	San Francisco	Oct.	2.24	.4	1.0	1.5	3.4	3	7	0	0
Del:	Wilmington	Oct.	2.23	.6	1.4	1.5	3.4	5	11	0	0
Fla:	Tampa	Oct.[a]	1.71	.6	1.0	1.3	2.3	4	6	34	58
Hawaii:	Honolulu	Oct.[a]	2.46	.5	1.2	1.4	3.5	3	8	0	0
Idaho:	Idaho Falls	Oct.[a]	2.11	1.1	2.4	1.5	3.1	7	14	0	0
Ky:	Louisville	Oct.	2.33	.6	1.5	1.7	3.9	6	15	0	0
La:	New Orleans	Oct.[a]	1.93	.7	1.4	1.5	3.0	8	16	0	0
Maine:	Portland	Oct.	1.92	.9	1.8	1.7	3.3	10	18	0	0
Mass:	Boston	Oct.	2.13	.6	1.4	1.2	2.5	6	14	0	0
Nebr:	Omaha	Oct.[a]	1.47	.7	1.0	1.5	2.2	5	7	0	0
Nev:	Carson City	Oct.	1.54	.5	.7	1.4	2.1	3	4	0	0
N. Mex:	Albuquerque	Oct.	2.58	.7	1.7	1.2	3.1	3	8	0	0
Ohio:	Cleveland	Oct.	.85	.6	.5	1.7	1.4	6	5	12	10
Oreg:	Portland	Oct.[a]	1.89	0.7	1.3	1.7	3.2	6	10	0	0
Pa:	Pittsburgh	Oct.[a]	2.22	.5	1.1	1.3	3.0	6	12	13	29
S.C:	Charleston	Oct.	1.70	.6	1.0	1.4	2.4	6	11	13	22
S. Dak:	Sioux Falls	Oct.[a]	.63	.5	.3	1.7	1.0	6	4	17	11
Tex:	Austin	Oct.[a]	2.07	.8	1.7	1.5	3.1	3	5	0	0
Utah:	Salt Lake City	Oct.[a]	2.32	.5	1.1	1.0	2.4	3	8	0	0
Wash:	Seattle	Oct.[a]	2.06	.5	1.1	1.3	2.8	6	13	0	0
Institutional average			1.82	0.6	1.2	1.5	2.7	5	9	5	7

[a] Food samples were collected fom two or more children who were not between the ages of 9 and 12.
Note: Strontium-89, iodine-131, and barium-140 were not detectable at any station during this period.

Table 2. 1970 annual average concentration and intake of stable elements and radionuclides in institutional total diets of children (9–12 years of age)[a]

Location of institution		Total weight (kg/day)	Calcium[b]		Potassium		Strontium-90[b]		Cesium-137	
			g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska:	Juneau[c]	1.42	0.4	0.6	1.6	2.3	3	4	13	19
	Palmer	1.23	.6	.7	1.5	1.7	6	7	13	15
Ariz:	Phoenix	1.59	.6	.9	1.4	2.2	5	9	0	0
Ark:	Little Rock[c]	1.20	.7	.8	1.6	1.9	10	12	9	11
Calif:	Los Angeles	1.35	.5	.6	1.1	1.5	3	4	0	0
	San Francisco[c]	1.98	.5	1.0	1.5	3.0	3	5	0	0
Del:	Wilmington	2.11	.7	1.6	1.5	3.2	5	10	1	2
Fla:	Tampa[c]	1.43	.5	.8	1.4	2.0	6	9	28	39
Hawaii:	Honolulu[c]	2.28	.4	1.0	1.4	2.3	1	3	3	8
Idaho:	Idaho Falls[c]	1.99	1.3	2.6	1.5	3.1	7	15	9	17
Ky:	Louisville	2.44	.6	1.5	1.7	4.0	7	17	6	16
La:	New Orleans[c]	1.61	.5	.9	1.4	2.3	7	12	2	3
Maine:	Portland	1.70	1.0	1.7	1.6	2.8	11	17	11	18
Mass:	Boston	2.13	.7	1.6	1.4	3.0	6	13	8	17
Miss:	Columbia[c,d]	2.09	1.1	2.2	1.5	2.9	9	18	16	35
Nebr:	Omaha[c]	1.80	1.0	1.7	1.6	2.9	5	9	1	2
Nev:	Carson City	1.58	.7	1.2	1.5	2.3	7	12	6	8
N. Mex:	Albuquerque	2.28	.8	1.8	1.4	3.1	3	7	2	5
Ohio:	Cleveland[c]	1.33	.8	1.1	1.6	2.1	8	11	8	10
Oreg:	Portland[c]	1.85	.6	1.1	1.8	3.3	3	5	3	7
Pa:	Pittsburgh[c]	2.25	.5	1.2	1.4	3.1	6	13	10	24
S.C:	Charleston[c]	1.84	.6	1.2	1.3	2.5	8	15	9	18
S. Dak:	Sioux Falls[c]	1.16	.7	.8	1.7	1.9	6	7	7	6
Tex:	Austin[c]	1.83	.8	1.4	1.5	2.8	4	6	1	2
Utah:	Salt Lake City[c]	2.31	.5	1.1	1.2	2.8	2	6	0	0
Wash:	Seattle[c]	2.14	.5	1.1	1.4	3.0	5	10	0	0
Network average		1.80	.7	1.2	1.5	2.6	6	10	6	11

[a] Strontium-89, iodine-131, and barium-140 were not detected at most stations during 1970. The one exception is as follows: February—11 pCi/kg of iodine-131 was reported in Cleveland, Ohio.
[b] Composite of monthly samples during first 6 months of year.
[c] Food samples were collected from two or more children who were not between the ages of 9 and 12.
[d] Nine-month sample.

Strontium-90 dietary intake averaged 9 pCi/day and cesium-137 intake averaged 7 pCi/day during this period. These results fall within Range I as defined by the Federal Radiation Council (*4*). Strontium-89, barium-140, and iodine-131 concentrations were below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level have been reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2-standard deviation analytical error. Accordingly, the minimum detectable limits are as follows:

Strontium-89	5 pCi/kg
Strontium-90	2 pCi/kg
Iodine-131	10 pCi/kg
Barium-140	10 pCi/kg
Cesium-137	10 pCi/kg

Annual average radionuclide concentrations and intakes are presented in table 2 for all stations. During 1970, the annual average intake for these institutions was 1.80 kg/day as compared to the network average of 1.87 kg/day observed from 1961 through 1969. The average levels of radionuclide concentrations are similar to previous years except that average concentrations of cesium-137 have been decreasing during the last few years.

REFERENCES

(*1*) ANDERSON, E. C., D. J. NELSON, JR. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

(*2*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1965. Radiol Health Data 6:548–554 (October 1965).

(*3*) PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1968. Radiol Health Data Rep 9:557–560 (October 1968).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January—March 1970	November 1970
April—June 1970	January 1971
July—September 1970	February 1971

XUM

XUM

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (2–4), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Interstate Carrier Drinking Water	1967–1969	December 1970
Kansas	January–December 1969	September 1970
Minnesota	July–December 1969	May 1971
North Carolina	January–December 1967	May 1969
New York	January–June 1969	June 1970
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	December 1970	May 1971
Washington	July 1968–June 1969	February 1971

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidence for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

XUM

Radioactivity in Minnesota Municipal Water Supplies, July-December 1969

Division of Environmental Sanitation
Minnesota Department of Health

The analysis of various Minnesota waters for radioactivity was initiated in 1956 as part of the Minnesota Water Pollution Control Program. This program was expanded in 1958 to include most of the municipal surface water supplies in the State, as well as selected lakes throughout the State.

As many as 25 surface streams and lakes involving 74 stations have been sampled. At present, nine surface streams and lakes used as municipal water supplies are sampled routinely (figure 1). "Grab" samples of raw and treated water are collected weekly at Hallock, East Grand Forks, Eveleth, Fairmont, and St. Paul. Beginning in November 1969, weekly samples from these stations were composited and analyzed on a monthly basis. Monthly samples are taken at Crookston, International Falls, and St. Cloud. Minneapolis tap water is analyzed weekly. No raw water is collected from the Minneapolis supply.

The samples are forwarded to the Division's laboratory, where they are analyzed for gross alpha and beta radioactivity. A 500-ml sample of water is evaporated in a 2-inch aluminum milk-bottle-lid planchet and counted in an internal-proportional gas-flow counter. Counter standardization is accomplished by adding known amounts of thallium-204 standard to solutions containing the normal range of solids.

[1] Data and information from "Survey of Environmental Radioactivity, July–December 1969." State of Minnesota Department of Public Health, University Campus, Minneapolis, Minn. 55440, Publication No. C00–651–82.

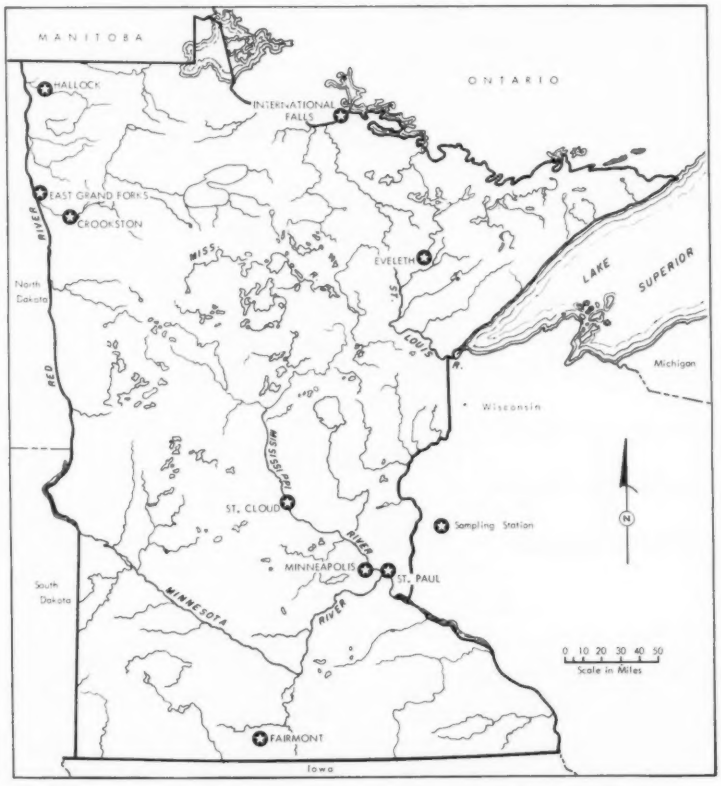

Figure 1. Minnesota surface water sampling locations

Table 1. Average gross beta radioactivity in Minnesota raw and treated water supplies, July–December 1969

Town and water source	Type of water	Average concentrations (pCi/liter)					
		July	Aug	Sept	Oct	Nov	Dec
Crookston, Red Lake River	Raw	NS	18	18	5	18	21
	Treated	NS	17	19	17	17	18
East Grand Forks, Red Lake River	Raw	[a]17 (4)	17 (4)	19 (4)	14 (4)	[b]20	[b]17
	Treated	8 (4)	9 (4)	9 (4)	8 (4)	[b]9	[b]8
Eveleth, St. Mary's Lake	Raw	11 (5)	13 (4)	13 (3)	10 (5)	[b]12	[b]12
	Treated	12 (5)	13 (4)	12 (3)	11 (5)	[b]11	[b]14
Fairmont, Budd Lake	Raw	12 (5)	10 (4)	9 (3)	9 (5)	[b]10	[b]12
	Treated	5 (5)	5 (4)	7 (3)	4 (5)	[b]4	[b]6
Hallock, Two Rivers-South Fork	Raw	20 (4)	21 (4)	19 (3)	19 (5)	[b]17	[b]24
	Treated	7 (4)	7 (4)	8 (3)	10 (5)	[b]10	[b]10
International Falls, Rainy River	Raw	8	10	9	10	10	6
	Treated	6	9	7	7	8	6
Minneapolis tap water	Treated	7 (4)	4 (4)	4 (4)	4 (4)	[b]4	[b]4
St. Cloud, Mississippi River	Raw	10	4	6	7	8	NA
	Treated	4	10	4	2	5	NA
St. Paul, Vadnais Chain of Lakes	Raw	10 (5)	10 (4)	11 (3)	9 (5)	[b]12	[b]10
	Treated	6 (5)	6 (4)	4 (3)	6 (5)	[b]5	[b]4

[a] Number in parenthesis gives number of samples averaged.
[b] Composite sample.
NA, no analysis.
NS, no sample.

Table 2. Average gross alpha radioactivity in Minnesota raw and treated water supplies, July–December 1969

Town and water source	Type of water	Average concentrations (pCi/liter)					
		July	Aug	Sept	Oct	Nov	Dec
Crookston, Red Lake River	Raw	NS	0	0	0	0	5
	Treated	NS	0	0	0	0	0
East Grand Forks, Red Lake River	Raw	[a]1 (4)	1 (4)	0 (4)	0 (4)	[b]0	[b]0
	Treated	0 (4)	0 (4)	0 (4)	0 (4)	[b]0	[b]0
Eveleth, St. Mary's Lake	Raw	0 (5)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
	Treated	0 (5)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
Fairmont, Budd Lake	Raw	3 (5)	5 (4)	1 (3)	4 (5)	[b]0	[b]0
	Treated	0 (5)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
Hallock, Two Rivers South Fork	Raw	0 (4)	1 (4)	0 (3)	0 (5)	[b]0	[b]0
	Treated	0 (4)	0 (4)	0 (3)	0 (5)	[b]0	[b]0
International Falls, Rainy River	Raw	0	0	0	0	0	0
	Treated	0	0	0	0	0	0
Minneapolis tap water	Treated	0 (4)	0 (4)	0 (4)	0 (4)	[b]0	[b]0
St. Cloud, Mississippi River	Raw	0	0	1	0	0	NA
	Treated	0	0	0	0	0	NA
St. Paul, Vadnais Chain of Lakes	Raw	0 (5)	0 (4)	1 (3)	0 (5)	[b]0	[b]0
	Treated	0 (5)	<1 (4)	0 (3)	<1 (5)	[b]0	[b]0

[a] Number in parenthesis gives number of samples averaged.
[b] Composite sample.
NA, no analysis.
NS, no sample.

Table 1 shows a summary of the monthly average gross beta radioactivity in Minnesota municipal water supplies from July–December 1969. Table 2 shows the gross alpha radioactivity in the same samples for the same period of time. Alpha concentrations reported as <1 pCi/liter were considered as 0 pCi/liter for averaging purposes.

The data obtained on gross beta radioactivity in Minnesota surface waters show a variation of concentrations, with no readily apparent trends. Variations in precipitation and flow rates of streams could contribute to this fluctuation. Monthly averages of gross beta radioactivity in Minnesota raw surface waters ranged from 2 to 24 pCi/liter, which is well below the Public Health Service Drinking Water Standards (*1*).

REFERENCE

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January—June 1969	January 1970

XUM

Tritium Surveillance System, July-December 1970

Office of Radiation Programs
Environmental Protection Agency

This is the first in a series of data articles on the Tritium Surveillance System which began in July 1970 and is an expansion of previous tritium surveillance activities conducted by the Office of Radiation Programs, Environmental Protection Agency (EPA). The principal effort in the past by the Office of Radiation Programs related to tritium releases has been the Tritium in Surface Water Network. This network was established in 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at surface water stations downstream from selected nuclear facilities. The network consisted of selected stations from existing water pollution sampling stations operated by the Water Quality Office of EPA. The final data from this network for January–June 1970 have been published previously (*1*).

Another effort of the Radiation Office was a tritium-in-precipitation program. This project was established in 1967 at selected Radiation Alert Network (RAN) stations covering the United States, including Alaska and Hawaii. The RAN is operated by the Office of Air Programs of EPA. The data from this project for July–December 1969 have been published previously (*2*). Due to the increased interest in tritium releases from nuclear facilities and the potential long-term accumulation in the environment, a national

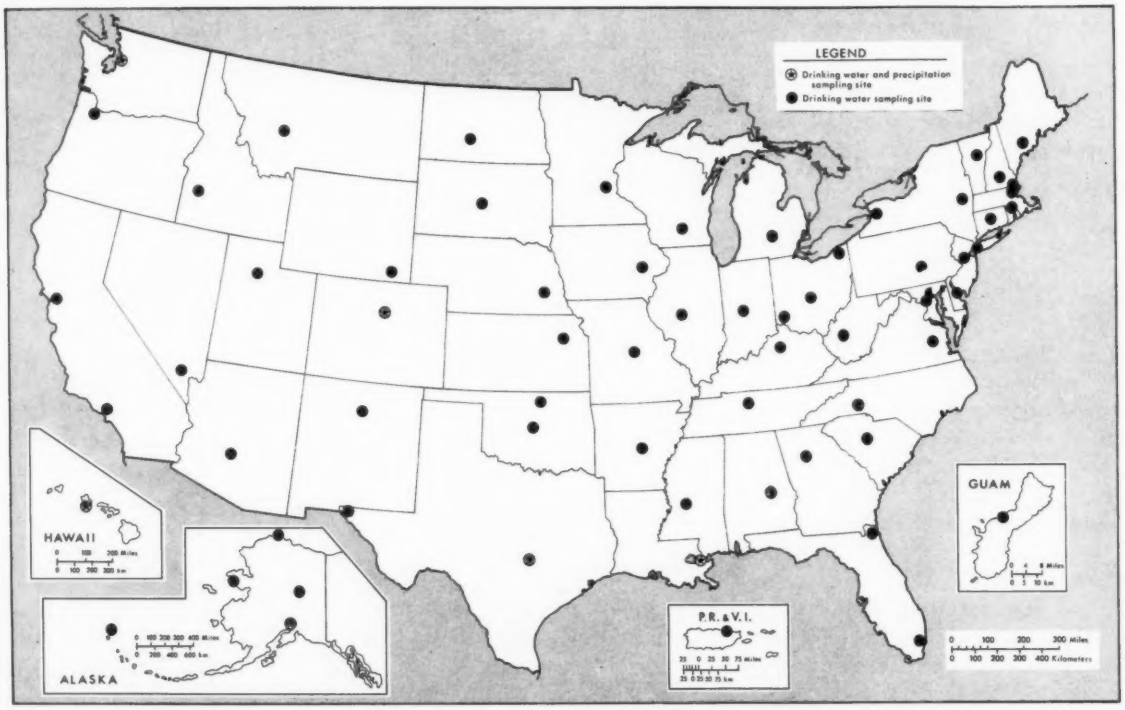

Figure 1. Drinking water and precipitation sampling locations for tritium surveillance system

system has been established to incorporate these projects or networks into one overall system.

Present network

The Tritium Surveillance System consists of 70 quarterly drinking water samples at the RAN stations, precipitation samples collected daily and analyzed monthly from 8 of the RAN stations (figure 1), and quarterly samples at 39 surface water stations (figure 2). The specific locations for the surface water sampling system were determined by examining the water drainage areas to assure that a representative sample from a large area or region was obtained, and if possible, incorporating several nuclear facility sites. All nuclear facilities that were operating through 1970, being constructed, or planned through 1975 were considered. Consideration was also given to the current surveillance programs of the States that will be involved in the collection of the samples. The surface water samples are collected quarterly either downstream from a nuclear facility or at a background station.

The tap water samples are collected by the RAN operators on a quarterly basis. The precipitation samples are also collected by the RAN operators on a daily basis.

All samples are sent to one of our laboratories for analysis. Due to the different sensitivity of procedures used by the three laboratories, the minimum detectable concentration varies. Analytical values which are not statistically significant at the 2-sigma confidence level have been reported as zero.

Results and discussion

Table 1 presents the tritium concentrations in drinking water at the RAN stations for 1970. Although the quarterly tap water collections did not begin until July 1970, a one-time collection of tap water during the first 6 months of 1970 is also included in table 1. The average tritium concentration was 0.3 nCi/liter for the first 6 months and 0.2 nCi/liter for each of the last two quarters.

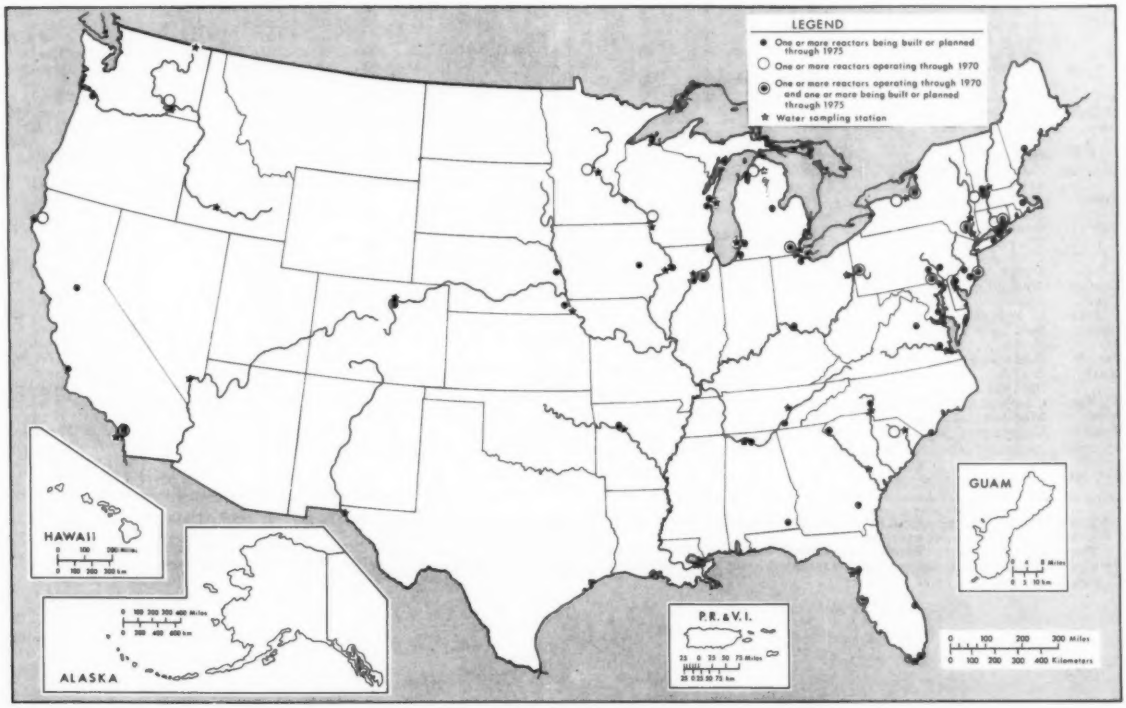
LEGEND
One or more reactors being built or planned through 1975
One or more reactors operating through 1970
One or more reactors operating through 1970 and one or more being built or planned through 1975
Water sampling station
HAWAII
ALASKA
GUAM
P.R. & V.I.

Figure 2. Surface water sampling locations for tritium surveillance system

XUM

Table 1. Tritium concentration in tap water, (RAN stations) January–December 1970

Location		Date collected (January–June)	Tritium concentration (nCi/liter ±2σ)	Date collected (July–September)	Tritium concentration (nCi/liter ±2σ)	Date collected (October–December)	Tritium concentration (nCi/liter ±2σ)
Ala:	Montgomery	3/25	[a]0	8/17	[a]0	10/2	[a]0
Alaska:	Adak	2/2	0.6±0.4	9/8	0.6±0.4	10/1, 12/29	[b,a]0.3
	Anchorage	NS		8/18, 9/7	[b,c].5	10/4, 10/13	[b,a]0
	Attu Island	NS		8/14	[a]0	10/1	.5±.4
	Fairbanks	2/5	.4± .4	8/11	[a]0	NS	
	Juneau	NS		9/8	.7± .4	10/5	.5±.4
	Kodiak	1/26	[a]0	NS		10/2	.4±.4
	Nome	NS		NS		NS	
	Point Barrow	2/6	1.1± .4	9/30	1.3± .4	NS	
	St. Paul Island	2/19	.9± .4	NS		10/7	.5±.4
Ariz:	Phoenix	NS		8/1	[a]0	NS	
Ark:	Little Rock	2/17	[a]0	8/7	[a]0	10/6	[a]0
Calif:	Berkeley	NS		8/11	[a]0	10/1	.6±.4
	Los Angeles	1/21	[a]0	8/7	[a]0	10/2	.5±.4
C.Z:	Ancon	4/6	[a]0	9/1	[a]0	11/4	[a]0
Colo:	Denver	NS		8/11, 9/23	[b,a]1.1	10/4, 10/27	[b,a]1.1
Conn:	Hartford	1/23	[d]0	8/11	[d]0	10/1	[d]0
Del:	Dover	NS		8/31	[d]0	10/1	[d]0
D.C:	Washington	2/4	[a]0	8/11	[a]0	10/15	[a]0
Fla:	Jacksonville	NS		7/30, 8/7	[a,b]0	10/5	[a]0
	Miami	2/4	[a]0	8/7	[a]0	10/5	[a]0
Ga:	Atlanta	2/6	[a]0	8/10	[a]0	10/5	.3±.2
Guam:	Agana	NS		NS		NS	
Hawaii:	Honolulu	NS		8/17	[a]0	10/8	[a]0
Idaho:	Boise	1/21	.7± .4	8/12	.5± .4	10/2	.9±.4
Ill:	Springfield	1/26	[d]0	8/7	.7± .6	10/1	[d]0
Ind:	Indianapolis	1/22	[d]0	8/31	[d]0	10/1	[d]0
Iowa:	Iowa City	1/26	.6± .4	8/11	[a]0	10/12	[a]0
Kans:	Topeka	1/21	[a]0	8/10	[a]0	10/5	.5±.4
Ky:	Frankfort	2/5	.3± .2	8/17	[a]0	10/7	[a]0
La:	New Orleans	2/6	[a]0	7/30	[a]0	10/8	[a]0
Maine:	Augusta	1/23	[d]0	8/11	[d]0	10/1	[d]0
Md:	Baltimore	2/5	.3± .2	8/12	[a]0	10/8	[a]0
	Rockville	6/15	[a]0	NS		NS	
Mass:	Lawrence	NS		8/31	[d]0	10/1	[d]0
	Winchester	1/26	[d]0	8/11	[d]0	10/1	[d]0
Mich:	Lansing	1/26	[d]0	8/12	[d]0	10/2	[d]0
Minn:	Minneapolis	NS		8/14, 9/14	[b,c]1.0	10/14, 10/14	[b,c].6
Miss:	Jackson	2/6	[a]0	8/7	[a]0	10/6	[a]0
Mo:	Jefferson City	1/22	[c]0	8/10	[c]0	10/1	[c]0
Mont:	Helena	NS		8/10, 9/3	[b,c]1.2	10/2	1.1±.4
Nebr:	Lincoln	1/27	.6± .4	8/10	[c]0	10/5, 11/17	[b,c].4
Nev:	Las Vegas	1/20	[c]0	8/7, 9/18	[b,c].8	NS	
N.H:	Concord	3/9	[d]0	8/11	[d]0	10/1	[d]0
N.J:	Trenton	NS		8/12	[d]0	NS	
N. Mex:	Sante Fe	1/21	.9± .4	NS		10/1, 10/2, 12/21	[b,c].4
N.Y:	Albany	1/26	[d]0	8/11	[d]0	10/1	[d]0
	Buffalo	NS		8/12	[d]0	10/1	[d]0
	New York City	1/26	[d]0	NS		NS	
N.C:	Gastonia	2/6	[a]0	8/7	[a]0	10/6	[a]0
N.Dak:	Bismarck	1/27	2.0± .4	9/15	1.0± .4	10/7	1.2±.4
Ohio:	Cincinnati	1/27	[d]0	NS		10/1	[d]0
	Columbus	1/22	[d]0	8/12	[d]0	10/1	[d]0
	Painesville	NS		8/12	[d]0	10/1	[d]0
Okla:	Oklahoma City	NS		8/11	[a]0	10/8	[a]0
	Ponca City	2/6	[a]0	8/10	[a]0	10/8	[a]0
Oreg:	Portland	NS		9/3	.6± .4	NS	
Pa:	Harrisburg	1/26	[d]0	8/12	[d]0	10/1	[d]0
P.R:	San Juan	NS		9/14	[a]0	NS	
R.I:	Providence	NS		8/11	[d]0	10/1	[d]0
S.C:	Columbia	2/20	[a]0	8/6	[a]0	10/6	[a]0
S.Dak:	Pierre	2/6	2.3± .4	8/31	1.7± .4	10/13	1.6±.4
Tenn:	Nashville	2/4	[a]0	8/10	[a]0	10/12	[a]0
Tex:	Austin	2/20	[a]0	NS		10/7	[a]0
	El Paso	4/3	[a]0	8/10	[a]0	10/8	[a]0
Utah:	Salt Lake City	2/6	.6± .4	NS		NS	
Vt:	Barre	1/29	[d]0	8/11	[d]0	10/1	[d]0
Va:	Richmond	2/17	[a]0	NS		10/8	[a]0
Wash:	Seattle	2/16	.7± .4	8/13	[c]0	NS	
	Spokane	2/2	[c]0	8/11	[c]0	10/1	[c]0
W. Va:	Charleston	2/20	[a]0	8/7	[a]0	10/5	[a]0
Wisc:	Madison	1/26	[d]0	8/31	[d]0	10/1	[d]0
Wyo:	Cheyenne	3/23	1.3± .4	8/10	.8± .4	10/2	1.3±.4
Average			0.3		0.2		0.2

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
[b] Average of two or more samples.
[c] The minimum detection limit for this sample was 0.4 nCi/liter. All values equal to or less than 0.4 nCi/liter have been reported as zero.
[d] The minimum detection limit for this sample was 0.6 nCi/liter. All values equal to or less than 0.6 nCi/liter have been reported as zero.
NS, no sample.

Table 2. Tritium concentration in surface water, July–December 1970

Location	Water source	Facility	Collection date (July–Sept)	Concentration (nCi/liter ±2σ)	Collection date (Oct–Dec)	Concentration (nCi/liter ±2σ)
Ala:						
Decatur	Tennessee River	Browns Ferry	7/29	0.4±0.2	10/17	[a]0
Ark:						
Russellville	Lake Dardanelle (Arkansas River)	Arkansas Nuclear	7/16	[a]0	12/15	[a]0
Calif:						
Eureka	Humboldt Bay	Humboldt Bay	9/11	[b]0	10/5	[b]0
San Onofre	Pacific Ocean	San Onofre	9/22	[c]2.5± .4	12/2	[b]0
Colo:						
Greeley	South Platte River	Fort St. Vrain	8/11	1.1± .4	11/8	[d]1.0±.4
Conn:						
East Haddam	Connecticut River	Connecticut Yankee and Vermont Yankee	8/13	3.5± .6	10/14	[c]0
Waterford	Long Island Sound	Millstone	8/13	[c]0	10/14	[c]0
Fla:						
Crystal River	Gulf of Mexico	Crystal River	8/11	[a]0	10/15	[a]0
Key Largo	Biscayne Bay	Turkey Point	8/6	[a]0	11/4	[a]0
Idaho:						
Buhl	Snake River	National Reactor Testing Station	NS		10/27	.4±.4
Ill:						
Moline	Mississippi River	Quad-Cities	NS		10/29	[c]0
Morris	Illinois River	Dresden and Argonne	NS		10/9	[c]0
La:						
New Orleans	Mississippi River	(Several)	9/3	.3± .2	10/13	[a]0
Md:						
Conowingo	Susquehanna River	Peach Bottom and Three Mile Island	8/13	[c]0	10/7	[c]0
Lusby	Chesapeake Bay	Calvert Cliffs	9/29	[c]0	11/17	[c]0
Mass:						
Rowe	Deerfield River	Yankee	8/14	8.2± .6	10/6	[c]0
Mich:						
Charlevoix	Lake Michigan	Big Rock Point	9/6	[c]0	NS	
Monroe	Lake Erie	Enrico Fermi	9/12	[c]0	NS	
South Haven	Lake Michigan	Palisades	9/8	[c]0	NS	
Minn:						
Monticello	Mississippi River	Monticello	NS		NS	
Nebr:						
Rulo	Missouri River	Fort Calhoun and Cooper	NS		10/5	1.0±.4
Nev:						
Boulder City	Colorado River	Background	9/7	1.2± .4	10/7, 12/18	[b,f]1.6
N.J:						
Bayside	Delaware River	Salem	8/31	[c]0	11/10	[c]0
N.Y:						
Ossining	Hudson River	Indian Point	8/21	[c]0	10/6	[c]0
Oswego	Lake Ontario	Nine Mile Point and R. E. Ginna	8/19	[c]0	10/1	[c]0
Poughkeepsie	Hudson River	Background	9/16	[c]0	10/14	[c]0
N.C:						
Charlotte	Catawba River	Wm. B. McGuire	8/27	.3± .2	12/29	.3±.2
S.C:						
Allendale	Savannah River	Savannah River Plant and Oconee	8/3	4.9± .3	12/18	10.3±.3
Hartsville	Lake Robinson	H. B. Robinson	7/15	[a]0	10/9	[a]0
Tenn:						
Kingston	Clinch River	Oak Ridge	7/6, 9/7	[a,f]1.2	10/16	2.6±.2
Tex:						
El Paso	Rio Grande River	Los Alamos	9/1, 9/2	[b,f]0	10/6	.5±.4
Vt:						
Vernon	Connecticut River	Vermont Yankee	7/31	[c]0	10/5	[c]0
Va:						
Surry	James River	Surry	8/13	[a]0	11/19	[a]0
Wash:						
Northport	Columbia River	Background	9/20	.9± .4	10/5, 10/18	[b,f].8
Pasco	Columbia River	Hanford	8/26	1.3± .4	10/2	1.0±.4
W. Va:						
Wheeling	Ohio River	Shippingport	8/25	[c]0	10/16	[c]0
Wisc:						
La Crosse	Mississippi River	La Crosse and Prairie Island	8/28	[c]0	10/6	[c]0
Two Creeks	Lake Michigan	Point Beach and Kewaunee	8/31	[c]0	10/12	[c]0
Average				0.8		0.6

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
[b] The minimum detection limit for this sample was 0.4 nCi/liter. All values equal to or less than 0.4 nCi/liter have been reported as zero.
[c] This sample was collected in San Clemente.
[d] This sample was collected in Denver.
[e] The minimum detection limit for this sample was 0.6 nCi/liter. All values equal to or less than 0.6 nCi/liter have been reported as zero.
[f] Average of two samples.
NS, no sample.

XUM

The radiation dose resulting from the observed tritium concentrations in the drinking water may be evaluated by using the relationship derived by Moghissi and Porter (*3*) from recommendations of the International Commission of Radiological Units and Measurements (*4*). Assuming that the concentration of tritium in all water taken into the body is equal to that found in the drinking water and also that the specific activity of tritium in the body is essentially the same as that in the drinking water, then the radiation dose may be estimated.

The highest individual concentration of tritium observed in the drinking water for the one time collection during the first 6 months of 1970 was 2.3 nCi/liter, 1.7 nCi/liter during the third quarter, and 1.6 nCi/liter during the fourth quarter. This corresponds to a dose of 0.4, 0.3, and 0.3 mrem/a, respectively, or less than 0.3 percent of the Federal Radiation Council's Radiation Protection Guide (170 mrem/a) for an average dose to a suitable sample of the exposed population.

The tritium concentrations for the surface water samples are given in table 2. The highest tritium concentration was 8.2 and 10.3 nCi/liter for the third and fourth quarters, respectively. Assuming that the specific activity of tritium in the body is essentially the same as that in surface water, these concentrations correspond to a dose of 1.4 and 1.8 mrem/a, respectively, or 0.8 and 1.0 percent of the Radiation Protection Guide.

The monthly analyses for tritium in precipitation samples at the 8 RAN stations are shown in table 3.

Miscellaneous tritium data

During the period from October 1969 through May 1970, the Division of Technology Assessment of the Office of Radiation Programs collected and analyzed surface water samples from 22 selected sites where nuclear power reactors were under construction or proposed and from one site where the reactor had recently started up. These samples were collected to determine the existing levels of tritium in surface water systems at or near power reactor sites. Lake or ocean samples were collected adjacent to the site or close to the planned discharge point, above the site, and below the site. For sites located on rivers, samples were collected adjacent to the site or near the planned discharge point and upstream from the site. A more comprehensive sampling was performed around the Calvert Cliffs facility. The data are presented in table 4 and the highest observed concentration was 1.2 nCi/liter.

REFERENCES

(*1*) BUREAU OF RADIOLOGICAL HEALTH. Tritium in surface water network, January–June 1970. Radiol Health Data Rep 11:638–639 (November 1970).

(*2*) BUREAU OF RADIOLOGICAL HEALTH. Tritium in precipitation, July–December 1969. Radiol Health Data Rep 11:354–355 (July 1970).

(*3*) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

(*4*) INTERNATIONAL COMMISSION OF RADIOLOGICAL UNITS AND MEASUREMENTS. Recommendations of the International Commission of Radiological Units and Measurements, National Bureau of Standards Handbook 85 (1964).

Table 3. Tritium concentration in precipitation from RAN stations, January–December 1970

Location	Tritium concentration[a] (nCi/liter ±2σ)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Alaska: Anchorage	0	0	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Ala: Montgomery	0	0	0	0	0.7±0.2	0	0.3±0.2	0	0	0	0	NS
Colo: Denver	NS	NS	0.4±0.2	0.6±0.2	1.1± .2	1.2±0.2	.6± .2	0.8±0.2	0	0.6±0.2	0.3±0.2	NS
Hawaii: Honolulu	0	NS	0	0	0	NS	0	0	0	0	0	0
La: New Orleans	NS	0	0	0	0	0	0	0	0	0	0	NS
N.C: Gastonia	0.3±0.2	0	.4± .2	0	0		.5± .2	0	0	0	0	0
Tex: Austin	0	NS	NS	0	0	NS	NS	NS	NS	NS	NS	NS
Wash: Seattle	0	0	0	.5± .2	0	0	.4± .2	0	0	0	0	0

[a] The minimum detection limit for these samples was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
NS, no sample.

Table 4. Tritium concentration in the vicinity of selected nuclear power reactor sites, October 1969–May 1970

Location	Water source	Facility	Date collected	Tritium concentration (nCi/liter ±2σ)
Ark: Russellville:	Lake Dardanelle (Arkansas River)	Arkansas Nuclear		
Upstream			1/27/70	[a]0
Downstream			1/27/70	[a]0
Fla: Ft. Pierce:	Atlantic Ocean	Hutchinson Island		
Atlantic Ocean			3/24/70	[a]0
Indian River			3/24/70	[a]0
Crystal River:	Gulf of Mexico	Crystal River		
Inlet			1/13/70	[a]0
Discharge			1/13/70	[a]0
Ga: Baxley:	Altamaha River	Edwin I. Hatch		
Upstream			2/5/70	0.4 ±0.2
Downstream			2/5/70	[a]0
Iowa: Cedar Rapids:	Cedar River	Duane Arnold		
Adjacent			10/16/69	1.1 ± .6
Upstream			10/16/69	[b]0
Md: Lusby:	Chesapeake Bay	Calvert Cliffs		
.32 miles E Cove Point			8/15/69	[c]0
.39 miles NE Rocky Point			8/15/69	[c]0
.87 miles NE site			8/15/69	[d]0
.28 miles NE site			8/15/69	[d]0
1.13 miles NE Calvert Black			8/15/69	.7 ± .6
1.32 miles E Scientists Cliff			8/15/69	.6 ± .6
Mouth of Severn River			8/15/69	[c]0
Mouth of Severn River			11/12/69	[f,a]0
Middle Bay Bridge			8/15/69	[c]0
Middle Bay Bridge			11/12/69	[e].34± .08
Middle Bay Bridge			11/12/69	[e].10± .07
Mass: Plymouth:	Atlantic Ocean	Pilgrim		
Adjacent			5/6/70	[b]0
North			5/6/70	[b]0
South			5/6/70	[b]0
Mich: Bridgman:	Lake Michigan	Donald C. Cook		
Adjacent			10/13/69	[b]0
North			10/13/69	.8 ± .7
South			10/13/69	[b]0
Lagoona Beach:	Lake Erie	Enrico Fermi		
Adjacent			10/22/69	[b]0
North			10/22/69	1.0 ± .7
South			10/22/69	[b]0
Minn: Red Wing:	Mississippi River	Prairie Island		
Adjacent			10/15/69	[b]0
Upstream			10/15/69	1.0 ± .7
N.H: Seabrook:	Atlantic Ocean	Seabrook		
Adjacent			10/23/69	[b]0
North			10/23/69	[b]0
South			10/23/69	[b]0
Inlet			10/23/69	[b]0
N.J: Salem:	Delaware River	Salem		
Adjacent			5/1/70	[b]0
Upstream			5/1/70	[b]0
N.Y: Brookhaven:	Long Island Sound	Shoreham		
Adjacent			4/30/70	[b]0
East			4/30/70	[b]0
West			4/30/70	[b]0
Lansing:	Lake Cayuga	Bell		
Adjacent			4/28/70	[b]0
North			4/28/70	[b]0
South			4/28/70	[b]0
Rochester:	Lake Ontario	R. E. Ginna		
Adjacent			4/27/70	[b]0
East			4/?7/70	[b]0
West			4/27/70	[b]0
N.C: Southport:	Cape Fear River	Brunswick		
Adjacent			[b]10/12/69	[a]0
Pa: Shippingport:	Ohio River	Beaver Valley		
Adjacent			10/17/69	[b]0
Upstream			10/17/69	[b]0
S.C: Hartsville:	Black Creek	H. B. Robinson		
Upstream			1/21/70	.4 ± .2
Downstream			1/21/70	[a]0
Seneca:	Keowee River	Oconee		
Upstream			1/16/70	[a]0
Downstream			1/16/70	[a]0
Tenn: Daisy:	Tennessee River	Sequoyah		
Upstream			3/10/70	.5 ± .2
Adjacent			3/10/70	.6 ± .2
Downstream			3/10/70	.4 ± .2
Va: Gravel Neck:	James River	Surry		
Upstream			1/27/70	[a]0
Downstream			1/27/70	[a]0
Mineral:	North Anna River	North Anna		
Upstream			1/27/70	[a]0
Downstream			1/27/70	[a]0

See footnotes at end of table.

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Table 4. Tritium concentration in the vicinity of selected nuclear power reactor sites October 1969–May 1970—Continued

Location	Water source	Facility	Date collected	Tritium concentrations (nCi/liter±2σ)
Wisc: Carlton:	Lake Michigan	Kewaunee		
Adjacent			10/14/69	1.1 ± .6
North			10/14/69	1.2 ± .6
South			10/14/69	.8 ± .7

[a] The minimum detection limit for this sample was 0.2 nCi/liter. All values equal to or less than 0.2 nCi/liter have been reported as zero.
[b] The minimum detection limit for this sample was 0.7 nCi/liter. All values equal to or less than 0.7 nCi/liter have been reported as zero.
[c] The minimum detection limit for this sample was 0.9 nCi/liter. All values equal to or less than 0.9 nCi/liter have been reported as zero.
[d] The minimum detection limit for this sample was 0.8 nCi/liter. All values equal to or less than 0.8 nCi/liter have been reported as zero.
[e] The minimum detection limit for this sample was 0.6 nCi/liter. All values equal to or less than 0.6 nCi/liter have been reported as zero.
[f] The minimum detection limit for this sample was 0.08 nCi/liter. All values equal to or less than 0.08 nCi/liter have been reported as zero.
[g] Sample was electrolytically enriched.
[h] Composite of three monthly samples.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates and Precipitation	January–June 1970	March 1971
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January–December 1968	April 1971

XUM

1. Radiation Alert Network January 1971

Office of Air Programs
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality and Emission Data, EPA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique during January 1971.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, January 1971

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Precipitation			
							Total depth (mm)	Field estimation of deposition		
			Maximum	Minimum	Average[a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	17	5	0	1	4	53	4	53	10
Alaska:	Anchorage	1	0	0	0	0				
	Attu Island	25	0	0	0	0				
	Fairbanks	0				0				
	Juneau	5	12	0	4	3	98	3	98	0
	Kodiak	2	0	0	0	0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	12	9	0	6	0				
Ark:	Little Rock	17	2	0	0	0				
Calif:	Berkeley	19	2	0	0	5	37	5	37	0
	Los Angeles	20	2	0	1	0				
C.Z:	Ancon	0				0				
Colo:	Denver	18	3	0	1	1	2	[b]		
Conn:	Hartford	19	0	0	0	6	40	6	40	5
Del:	Dover	19	0	0	0	0				
D.C:	Washington	22	0	0	0	0				
Fla:	Jacksonville	20	2	0	0	4	56	4	56	8
	Miami	12	0	0	0	1	13	1	13	0
Ga:	Atlanta	18	2	1	1	1	50	1	50	32
Guam:	Agana	0				0				
Hawaii:	Honolulu	25	1	0	0	7	97	[b]		
Idaho:	Boise	20	2	0	0	9	58	9	58	1
Ill:	Springfield	1	1	1	1	0				
Ind:	Indianapolis	19	2	0	0	0				
Iowa:	Iowa City	19	1	0	0	1	54	1	54	17
Kans:	Topeka	20	1	0	0	1	20	1	20	0
Ky:	Frankfort	15	0	0	0	0				
La:	New Orleans	19	1	0	0	4	47	[b]		
Maine:	Augusta	12	1	0	0	4	31	4	31	0
Md:	Baltimore	19	1	0	0	4	33	4	33	0
Mass:	Lawrence	20	0	0	0	3	26	3	26	0
	Winchester	20	0	0	0	4	33	4	33	0
Mich:	Lansing	19	0	0	0	0				
Minn:	Minneapolis	20	1	0	0	7	13	7	13	1
Miss:	Jackson	14	0	0	0	3	107	3	107	9
Mo:	Jefferson City	20	3	0	1	1	32	1	32	0
Mont:	Helena	13	1	0	0	1	11	1	11	0
Nebr:	Lincoln	18	4	0	2	1	32	1	32	12
Nev:	Las Vegas	18	4	0	2	0				
N.H:	Concord	0				0				
N.J:	Trenton	18	0	0	0	6	56	6	56	1
N. Mex:	Santa Fe	16	2	0	1	1	8	1	8	0
N.Y:	Albany	1	0	0	0	0				
	Buffalo	18	0	0	0	0				
	New York City	0				0				
N.C:	Gastonia	16	5	0	1	4	75	1	59	0
N. Dak:	Bismarck	20	1	0	0	5	21	5	21	1
Ohio:	Cincinnati	0				0				
	Columbus	0				0				
	Painesville	19	2	0	1	3	10	3	10	3
Okla:	Oklahoma City	8	1	1	1	0				
	Ponca City	20	4	0	1	1	38	1	38	0
Oreg:	Portland	20	1	0	0	11	198	10	173	5
Pa:	Harrisburg	13	0	0	0	0				
P.R:	San Juan	0				0				
R.I:	Providence	17	1	0	0	0				
S.C:	Columbia	18	2	0	1	4	84	4	84	0
S. Dak:	Pierre	20	2	0	1	0				
Tenn:	Nashville	20	1	0	0	5	62	5	62	5
Tex:	Austin	1	2	2	2	0				
	El Paso	0				0				
Utah:	Salt Lake City	27	2	0	1	4	11	4	11	0
Vt:	Barre	20	1	0	0	7	21	7	21	3
Va:	Richmond	19	1	0	0	6	55	6	55	11
Wash:	Seattle	8	0	0	0	7	80	[b]		
	Spokane	18	1	0	0	0				
W. Va:	Charleston	18	1	0	0	5	38	4	37	5
Wisc:	Madison	18	0	0	0	6	69	5	68	5
Wyo:	Cheyenne	20	5	0	1	1	10	1	10	3
Network summary		970	12	0	1	151	52	4	44	4

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

XUM

2. Canadian Air and Precipitation Monitoring Program,[1] January 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for January 1971 are presented in table 2.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, January 1971

Station	Number of samples	Air surveillance, gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.1	0.0	0.1	83	2.00
Coral Harbour	4	.1	.1	.1	39	.68
Edmonton	4	.1	.0	.1	10	.53
Ft. Churchill	4	.1	.1	.1	40	.78
Fredericton	4	.1	.1	.1	15	.77
Goose Bay	4	.1	.0	.0	7	.62
Halifax	4	.1	.0	.1	15	1.38
Inuvik	3	.1	.1	.1	81	.84
Montreal	4	.1	.0	.1	11	.68
Moosonee	4	.1	.1	.1	8	.17
Ottawa	4	.1	.0	.1	12	.79
Quebec	3	.1	.0	.1	12	1.07
Regina	4	.1	.1	.1	19	.31
Resolute	1	.1	.1	.1	78	.14
St. John's, Nfld.	3	.0	.0	.0	NS	NS
Saskatoon	4	.1	.1	.1	15	.39
Sault Ste. Marie	NS				9	.71
Thunder Bay	4	.1	.1	.1	88	2.10
Toronto	1	.0	.0	.0	NS	NS
Vancouver	4	.1	.0	.0	NS	NS
Whitehorse	4	.1	.1	.1	29	.42
Windsor	4	.1	.0	.0	19	.46
Winnipeg	4	.1	.1	.1	38	.40
Yellowknife	4	.1	.1	.1	24	.47
Network summary	83	0.1	0.0	0.1	31	0.75

NS, no sample.

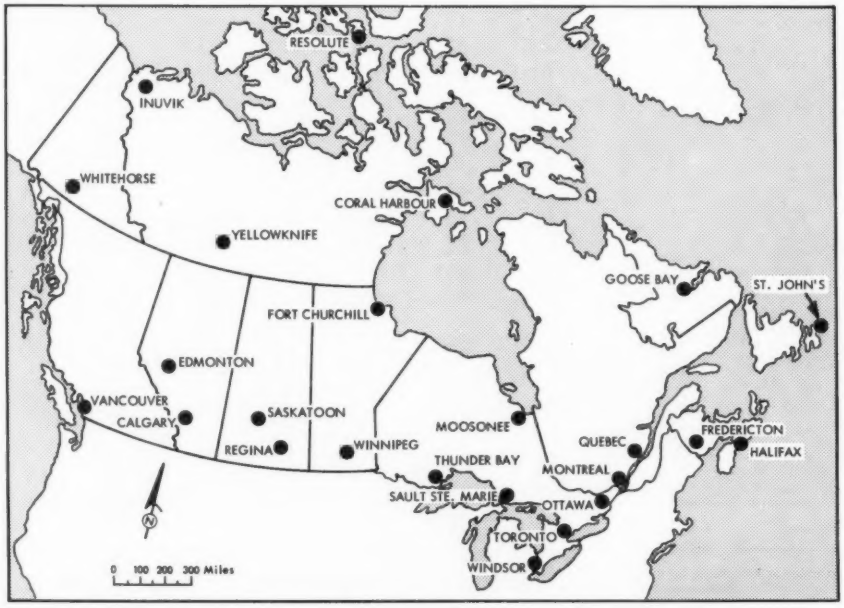

Figure 2. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program January 1971

Pan American Health Organization and *Environmental Protection Agency*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The January 1971 air monitoring results from the participating countries are given in table 3.

Figure 3. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, January 1971

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	NS			
Bolivia:	La Paz	12	0.05	0.00	0.02
Chile:	Santiago	31	.38	.08	.21
Colombia:	Bogota	18	.06	.01	.03
Ecuador:	Cuenca	NS			
	Guayaquil	NS			
	Quito	NS			
Guyana:	Georgetown	4	.06	.02	.04
Jamaica:	Kingston	NS			
Peru:	Lima	20	.33	.02	.15
Venezuela:	Caracas	7	.06	.01	.03
West Indies:	Trinidad	15	.20	.01	.09
Pan American summary		107	0.38	0.00	0.11

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

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(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for Argonne National Laboratory and Lawrence Radiation Laboratory.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Argonne National Laboratory January–June 1970

University of Chicago
Lemont, Ill.

The radioactivity of the environment is determined on a continuing basis by measuring the radioactivity in naturally occurring materials collected both on and off the Argonne National Laboratory site. Since radioactivity is usually spread by air and water, the environmental monitoring program at Argonne has concentrated on these media. The sampling locations discussed in this report are shown in figures 1 and 2.

Air monitoring

The radioactivity of particulate matter in air was determined by drawing air through filter paper at a known rate and measuring the radioactivity of the particles collected by the paper. The samples were collected continuously at seven locations on the Argonne site and at five locations off the site. At one location on the site the filter paper was changed daily; at all other locations the filter papers were changed at weekly intervals. The daily samples record short-term changes in radioactivity, while the weekly samples are used to compare onsite and offsite activities. The alpha and beta radioactivity in air-filter samples are summarized in table 1; the average concentration of gamma-ray emitters as determined by gamma ray spectrometry are summarized in table 2. The alpha radioactivity concentrations were normal and in the range found in previous years. As in the past, much of the beta and gamma radioactivity was due to fission and neutron activation products from nuclear detonations, although about one-third of the gamma radioactivity and a smaller fraction of the beta radioactivity was due to beryllium-7, produced in the stratosphere by cosmic-ray interactions. The concentrations of total beta radioactivity and of all the gamma-ray emitters for which positive results were obtained, increased steadily from January to June. This variation was probably due to the increased stratospheric fallout usually observed in the spring. The absence of short-lived fission products early in the year and the sharp increase in 40-day half-life ruthenium-103 and 65-day half-life zirconium-95 in the spring imply that most of the fission products were pro-

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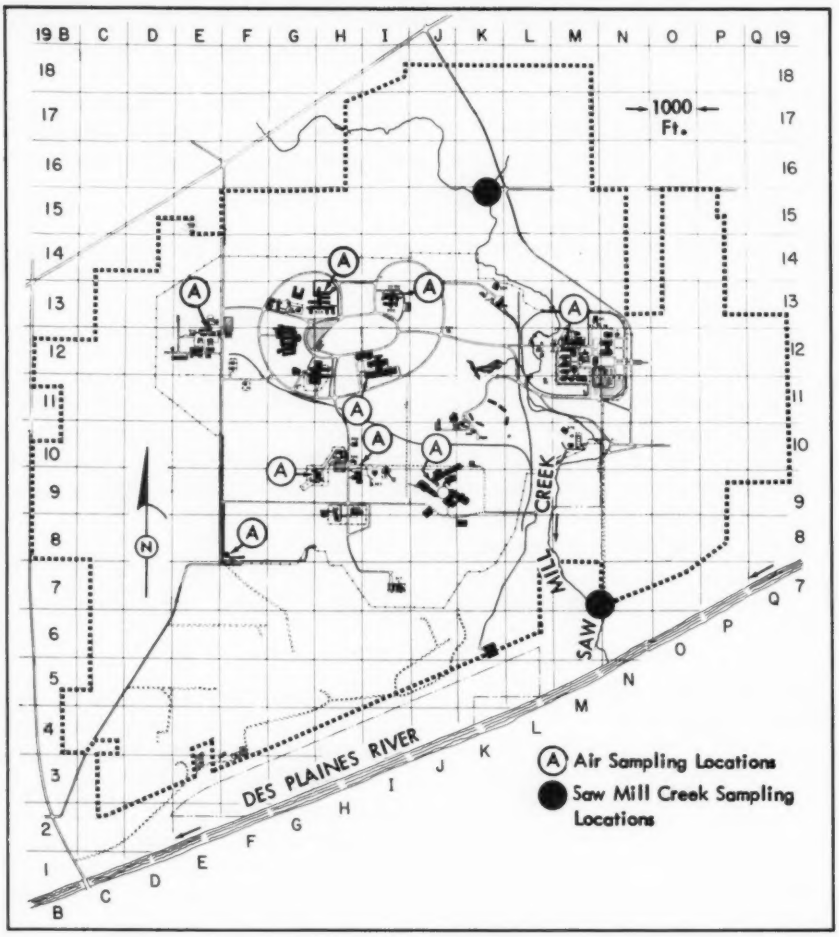

Figure 1. Onsite sampling locations at Argonne National Laboratory

Table 1. Alpha and beta radioactivity in air-filter samples[a] Argonne National Laboratory, January–June 1970

Period (1970)	Location	Number of samples	Alpha radioactivity (fCi/m³)			Beta radioactivity (pCi/m³)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	Onsite	27	3.2	1.1	10.6	0.08	0.03	0.11
	Offsite	17	3.2	1.2	8.2	.08	.03	.15
February	Onsite	22	2.6	1.1	4.4	.12	.06	.21
	Offsite	17	5.1	1.6	10.8	.14	.08	.20
March	Onsite	21	3.1	1.8	4.5	.17	.09	.30
	Offsite	22	3.7	2.0	8.0	.18	.08	.27
April	Onsite	23	3.1	2.2	5.7	.28	.16	.60
	Offsite	19	4.3	2.0	7.8	.31	.15	.61
May	Onsite	18	3.9	1.8	7.9	.46	.25	.69
	Offsite	23	6.6	1.9	12.7	.51	.18	1.16
June	Onsite	26	4.4	1.0	11.7	.63	.33	1.09
	Offsite	21	4.1	1.0	9.6	.61	.36	1.00
Summary	Onsite	137	3.4	1.0	11.7	0.29	0.03	1.09
	Offsite	119	4.5	1.0	12.7	0.31	0.03	1.16

[a] These results were obtained by measuring the samples 4 days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products.

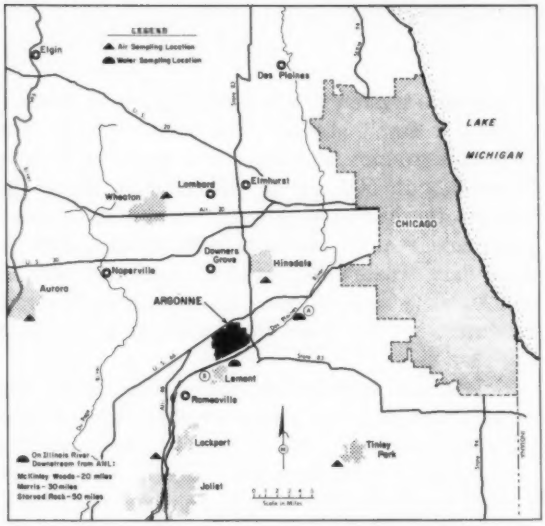

Figure 2. Location of Argonne National Laboratory (including some offsite sampling stations)

duced late in 1969 and were injected into the atmosphere at high altitudes. The average beta radioactivity for January–June 1970 was about 50 percent greater than in the corresponding period for 1969, primarily because of increased zirconium-niobium-95 concentrations.

The same fission products detected in the air filter samples were also present in precipitation samples, and the beta and gamma radioactivity in these samples also increased during the spring months. Composite large volume rain samples were also analyzed monthly for iron-55. The average monthly concentrations ranged from 3 to 400 pCi/m² of surface, about one-half of 1969 values. Iron-55 is a neutron activation product and was produced mainly in nuclear tests conducted in September and October 1961. Therefore, the above concentrations have been corrected for decay to October 15, 1961, for comparison purposes.

Air was also sampled continuously for radioiodine with activated charcoal in areas 200 and 300 because of the possibility of iodine releases in these areas. No iodine radioactivity was detected at either location.

Air sampling for argon-41 (a beta-particle emitter with a 1.8 hour half-life that is produced in an operating reactor by the action of neutrons on the stable argon-40 in air) was conducted near the Juggernaut reactor (Building 335) from January through April. On May 1, the reactor was shut down. The results are tabulated in table 3. These concentrations are based on 1-minute grab samples taken at a position downwind from the reactor at a point favorable for argon-41 detection after the reactor has been in operation for several hours. Therefore, the actual average concentrations in the vicinity of the reactor were much less than the values in the table.

Table 2. Gamma-ray radioactivity in air-filter samples Argonne National Laboratory, January–June 1970

Radionuclide	Location	Concentration[a] (pCi/m³)						
		January	February	March	April	May	June	Summary
Barium-lanthanum-140	Onsite	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Beryllium-7	Onsite	.05	.08	.09	.12	.10	.10	.09
	Offsite	.04	.09	.10	.09	.12	.09	.09
Cerium-141	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Cerium-144	Onsite	.01	.02	.03	.05	.09	.12	.05
	Offsite	.01	.02	.03	.06	.10	.12	.06
Cesium-137	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Iodine-131	Onsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
	Offsite	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Ruthenium-103	Onsite	< .01	< .01	< .01	.01	.02	.02	.01
	Offsite	< .01	< .01	< .01	.01	.02	.02	.01
Ruthenium-rhodium-106	Onsite	.02	.02	.02	.04	.08	.08	.04
	Offsite	.02	.03	.03	.04	.07	.08	.05
Zirconium-niobium-95	Onsite	.01	.02	.04	.10	.16	.17	.08
	Offsite	.01	.03	.05	.12	.16	.17	.09

[a] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

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Table 3. Argon-41 concentrations, near Juggernaut Reactor, January–April 1970[a]

Month (1970)	Number of samples	Number of samples >20 nCi/m³	Concentration[b] (nCi/m³)		Percent of AEC standard	
			Average	Maximum	Average	Maximum
January	32	6	26	153	65	383
February	32	7	30	334	75	834
March	32	11	25	85	63	213
April	25	7	20	79	50	198
Summary	121	31	25	334	63	834

[a] On May 1, the reactor was shut down.
[b] Minimum detectable concentration—20 nCi/m³.

Air was sampled for tritiated (hydrogen-3) water vapor, 50-yards west of the CP-5 reactor as well as 100-yards downwind from the reactor. Each sample was collected for a 24-hour period. The results are given in table 4. The results were positive in all cases, although the concentrations were well below the AEC standards. This nuclide is produced continuously while the reactor is in operation by the action of neutrons on the heavy water used for moderating and cooling. Occasional air samples were also collected 2,000 yards from the reactor to serve as controls. In these samples the tritium concentrations ranged from 7 to less than 2 pCi/m³. The average concentration for this period was 30 percent higher than during the first 6 months of 1969, but about 30 percent lower than the 1969 yearly average. Although the reactor has not been in operation since January 1969, the heavy water containing the long-lived tritium was handled while the reactor was undergoing modification, and small quantities evidently escaped from the building.

Table 4 Tritium concentrations near CP-5 reactor January–June 1970

Month (1970)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard	
		Average	Minimum	Maximum	Average	Maximum
January	13	69	3	221	0.03	0.11
February	10	97	3	298	.05	.15
March	20	150	4	586	.08	.29
April	38	570	4	4,730	.29	2.37
May	36	350	9	2,530	.18	1.27
June	34	410	15	2,640	.21	1.32
Summary	151	270	3	4,730	0.14	2.37

Water monitoring

Argonne wastewater is discharged into Sawmill Creek, a small stream that runs through the Argonne grounds and flows into the Des Plaines River about 500 yards downstream from the wastewater discharge. Sawmill Creek was sampled upstream from the Argonne site and downstream from the wastewater outfall to determine if radioactivity was added to the stream in Argonne wastewater. The sampling locations are shown in figure 2.

Below the wastewater outfall the creek was usually sampled five times weekly. Since it was impractical to analyze all the samples for all the radionuclides and elements desired, equal portions of the individual samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Above the site, samples were collected twice monthly and at least one sample each month was analyzed for each radionuclide of interest. The total alpha and beta radioactivities found in Sawmill Creek during January–June 1970 are given in table 5. Upstream from the Argonne site, the alpha activity was due primarily to radioactive nuclides that occur naturally in the stream. Any additional activity downstream would indicate a detectable contribution from Argonne wastewater. The results show that Argonne wastewater did not increase the alpha radioactivity in Sawmill Creek, and on some days the wastewater evidently contained less alpha radioactivity than upstream water.

The alpha-particle emitters most likely to be present in Argonne wastewater are isotopes of uranium, plutonium, and thorium. The alpha radioactivity in the creek water due to these elements is summarized in table 6. The concentrations were normal at both locations and low compared to the AEC standards. Comparison of these concentrations with the total alpha radioactivity indicates that most of the alpha activity in the creek was due to uranium. Based on the uranium concentrations at both locations and on a dilution factor of 8 for wastewater into the creek, the uranium content of the wastewater averaged about 3.2 pCi/liter during this period.

In addition to the natural beta radioactivity

Table 5. Nonvolatile alpha and beta radioactivity in Sawmill Creek water Argonne National Laboratory, January–June 1970

Month	Location[a]	Number of samples	Alpha radioactivity (pCi/liter)			Beta radioactivity (pCi/liter)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
January	Upstream	2	2.9	2.7	3.2	26	25	27
	Downstream	19	2.9	2.5	3.6	15	10	20
February	Upstream	2	4.1	3.1	5.1	10	8.1	12
	Downstream	20	2.2	1.7	2.8	13	10	17
March	Upstream	2	2.5	2.2	2.7	17	15	18
	Downstream	18	1.4	.4	2.0	16	11	27
April	Upstream	2	1.8	.8	2.8	11	10	12
	Downstream	19	1.8	1.4	2.0	10	7.8	12
May	Upstream	2	1.5	1.5	1.6	12	10	14
	Downstream	24	2.1	1.2	2.6	14	10	17
June	Upstream	2	2.1	2.1	2.2	19	18	20
	Downstream	20	1.4	1.0	1.8	14	12	17
January–June summary	Upstream	12	2.5	0.8	5.1	16	8.1	27
	Downstream	120	2.0	.4	3.6	14	7.8	27

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

Table 6. Alpha-emitting elements in Sawmill Creek water Argonne National Laboratory, January–June 1970

Element	Location[a]	Number of samples	Concentration[b] (pCi/liter)			Percent of AEC standard[c]	
			Average	Minimum	Maximum	Average	Maximum
Uranium	Upstream	6	1.7	0.7	2.6	0.004	0.007
	Downstream	58	1.9	.9	3.2	.005	.008
Plutonium	Upstream	6	—	—	<.05	—	<.001
	Downstream	57	—	—	<.05	—	<.001
Thorium	Upstream	6	<.05	<.05	.07	<.003	.004
	Downstream	57	<.05	<.05	.07	<.003	.004

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).
[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.
[c] Standards are: uranium-238, 40 nCi/liter; plutonium-239 (soluble), 5 nCi/liter; thorium-232 (soluble), 2 nCi/liter.

Table 7. Beta-emitting radionuclides in Sawmill Creek water Argonne National Laboratory, January–June 1970

Radionuclide	Location[a]	Number of samples	Beta radioactivity[b] (pCi/liter)			Percent of AEC standard	
			Average	Minimum	Maximum	Average	Maximum
Barium-140	Upstream	6	—	—	< 2	—	<0.007
	Downstream	60	—	—	< 2	—	<< .007
Cerium-144	Upstream	12	—	—	<10	—	<< .1
	Downstream	120	—	—	<10	—	<< .1
Cesium-137	Upstream	4	—	—	< .5	—	<< .003
	Downstream	78	<0.5	<0.5	2.2	<.0003	.011
Cobalt-58	Upstream	12	—	—	< 5	—	<< .005
	Downstream	120	—	—	< 5	—	<<< .005
Cobalt-60	Upstream	12	—	—	< 3	—	<< .006
	Downstream	120	—	—	< 3	—	<< .006
Tritium	Upstream	6	560	440	920	.019	.031
	Downstream	120	1,310	440	9,970	.044	.33
Iodine-131	Upstream	0	—	—	—	—	—
	Downstream	120	—	—	< 3	—	<1
Strontium-89	Upstream	6	—	—	<< 2	—	<< .07
	Downstream	60	—	—	< 2	—	<< .07
Strontium-90	Upstream	6	1.9	.5	3.6	.6	1.2
	Downstream	60	1.4	.6	2.1	.5	.7
Technetium-99	Upstream	4	—	—	<< .5	—	<.0002
	Downstream	78	—	—	< .5	—	<.0002
Thorium-protactinium-234	Upstream	6	1.4	.6	2.1	.007	.011
	Downstream	58	1.5	.7	2.6	.008	.013

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).
[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

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in the creek, beta radioactivity from nuclear detonations was detected at both sampling locations and beta radioactivity from Argonne wastewater was found in some samples below the outfall. The normal beta radioactivity is approximately 5 pCi/liter above the site and 3 to 5 pCi/liter below the site, depending on the relative amounts of creek and wastewater. The Argonne contribution to the total nonvolatile beta radioactivity below the outfall during the first half of 1970 is estimated to be approximately 2 pCi/liter, about the same as in 1969. The remaining activity at both locations, 8 to 10 pCi/liter, was due to the fallout and naturally-occurring radioactivity. The fallout level was about the same as during 1969.

The results of analysis of Sawmill Creek water for specific beta-emitting nuclides are summarized in table 7. The principal beta-particle emitter added to the creek by Argonne wastewater was tritium. The wastewater increased the tritium content of the Creek by about a factor of two. This radionuclide, present as water (HTO), is not included in the total beta radioactivity in table 5 because this activity is determined by evaporating the water and measuring the nonvolatile residue. Separate samples were analyzed specifically for tritium. Although small amounts are produced by cosmic-ray interactions with the atmosphere, the bulk of the tritium in above-site water originated in nuclear detonations. Although some of the other nuclides listed were also added to the creek by fallout, the total concentration, regardless of source, must be used in assessing the health hazard of a radioactive nuclide not naturally present in the environment. The percent of the AEC standard given in the table was calculated on this basis. As indicated in the table, the beta radioactivities in the creek were very low compared to the AEC standards.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne wastewater to the environmental radioactivity. The Des Plaines River was sampled monthly above the mouth of Sawmill Creek and weekly below the mouth to determine if the radioactivity in the creek has any effect on the radioactivity in the river. The total radioactivity is summarized in table 8, and the results of analysis for specific elements and radionuclides are given in table 9. Tritium was the only nuclide whose concentration was higher below the mouth of Sawmill Creek, and the additional activity at this location evidently originated in Argonne wastewater. However, the average and maximum concentrations below the creek amounted to only 0.02 and 0.05 percent, respectively, of the AEC standards. The concentration of tritium in the river above the creek is similar to that found

Table 8. Average radioactivity in Des Plaines and Illinois River water, Argonne National Laboratory January–June 1970

Location	Concentration (pCi/liter)			
	Nonvolatile alpha radioactivity	Uranium	Nonvolatile beta radioactivity	Tritium
Des Plaines River[a] (above Sawmill Creek)	[b] 2.8 (6)	—	16 (6)	630 (3)
Des Plaines River[b,c] (below Sawmill Creek)	3.1 (25)	2.1 (6)	16 (25)	710 (21)
Illinois River[d]	1.9	1.5	10	—

[a] Sampled near Route 45, upstream from the mouth of Sawmill Creek.
[b] Number in parenthesis is number of samples.
[c] Sampled near Lemont, downstream from the mouth of Sawmill Creek.
[d] Sample collected on June 11 at McKinley Woods opposite the Dresden Nuclear Power Plant.

Table 9. Radioactivity in Des Plaines River water Argonne National Laboratory, January–June 1970

Radionuclide	Location[a]	Number of samples	Concentration[b] (pCi/liter)		
			Average	Minimum	Maximum
Barium - lanthanum-140	Upstream	3	—	—	< 2
	Downstream	6	—	—	< 2
Cerium-144	Upstream	6	—	—	<10
	Downstream	25	—	—	<10
Cobalt-58,-60	Upstream	6	—	—	<10
	Downstream	25	—	—	<10
Tritium	Upstream	3	630	580	670
	Downstream	21	710	<400	1,640
Plutonium (alpha)	Upstream	3	—	—	< .05
	Downstream	7	—	—	< .05
Strontium-89	Upstream	3	—	—	< 2
	Downstream	6	—	—	< 2
Strontium-90	Upstream	3	1.7	1.1	2.4
	Downstream	6	1.5	< .5	2.4
Thorium (alpha)	Upstream	3	—	—	< .05
	Downstream	7	—	—	< .05
Thorium - protactinium-234	Upstream	—	—	—	—
	Downstream	6	1.7	1.0	2.6
Uranium (alpha)	Upstream	—	—	—	—
	Downstream	6	2.1	1.4	3.3

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).
[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

last year in the Des Plaines River and to that found in other streams in the area. Below the mouth of the creek, the concentration decreased to one-third of the 1969 average.

The concentrations of the other radionuclides and the total alpha and beta radioactivities were in their normal ranges at both locations. The annual average beta radioactivity was about the same as in 1969. The natural nonvolatile beta radioactivity in the river is 5 to 10 pCi/liter, and the excess (about 7 pCi/liter) was attributed to fallout. The total radioactivity in samples of Illinois River water were normal and similar to that found in other streams in the area. No evidence of radioactivity from Argonne was detected.

Radioactivity in milk

Raw milk was collected monthly from a local dairy farm and analyzed for several fission products. Strontium-89, iodine-131, and barium-140 were not present in concentrations greater than the minimum detectable amounts of 20 pCi/liter for iodine-131, and 3 pCi/liter for the other two radionuclides. The strontium-90 and cesium-137 concentrations are given in table 10. These two radionuclides are long-lived fission products from past nuclear tests and their presence in milk is not related to Argonne operations. The strontium-90 and cesium-137 concentrations during the first half of 1970 were nearly unchanged from the corresponding period of 1969.

Table 10. Fission product concentration in milk January–June 1970

Date collected	Concentrations (pCi/liter)	
	Cesium-137	Strontium-90
January 6	18	1.8
February 3	10	4.1
March 3	18	6.6
April 8	23	6.6
May 6	18	7.2
June 3	27	9.8
Average	19	6.0

Conclusion

Argonne's contribution to the environmental radioactivity was primarily limited to tritium and argon-41 in the air and to tritium in water from Sawmill Creek and the Des Plaines River. The only activity detected off the site were the low levels of tritium in the two streams.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January—June 1969	July 1970
July—December 1969	January 1971

2. Lawrence Radiation Laboratory[2] January–June 1970

University of California
Berkeley, Calif.

Berkeley site

The Berkeley site of the Lawrence Radiation Laboratory (LRL) is situated on the western slope of the range of hills running along the eastern side of San Francisco Bay. The laboratory area is largely separate from the main campus of the University (figure 3).

To the north and south of the laboratory area are residential areas of the cities of Berkeley and Oakland. The Berkeley campus of the University of California is on the west; to the east are the Lawrence Hall of Science and the Space Sciences Laboratory, beyond them lies uninhabited watershed land and the Tilden Regional Park.

The most prevalent wind direction is westerly. During the summer months, the afternoon sea breeze establishes a very pronounced prevailing westerly wind direction. At other times, the direction is less predictable. Annual rainfall is 23 inches, almost all of which falls between November 1 and May 1. The prevailing wind direction during precipitation is southerly.

The laboratory carries on a wide ranging program of general research in the fields of both physical and biological sciences. Facilities include a number of large accelerators and various

[2] Summarized from "Results of Environmental Radioactivity Sampling Program, January–June 1970," Lawrence Radiation Laboratory, Livermore and Berkeley, Calif.

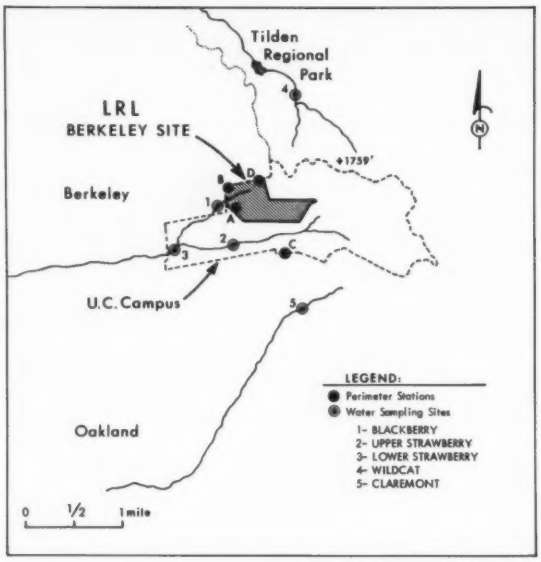

Figure 3. Environmental sampling locations at the Berkeley site, Lawrence Radiation Laboratory

physics, chemistry, biology, and medical research laboratories.

The basic policy at LRL has long been to prevent, as far as possible, any release of radioactive material to the environment, no matter how small. No deliberate releases are sanctioned, except where no practical method for containment has yet been developed, and quantities are small compared with standards established by the International Commission on Radiological Protection (ICRP) and the Atomic Energy Commission (AEC).

The most sensitive measurements of releases are those taken closest to the source itself, before dilution makes detection of small quantities more difficult. The stack sampling program, therefore, provides the most useful information for controlling releases to the atmosphere. Over 100 separate exhausts from hoods and glove-box manifolds are sampled. The total quantity released from these stacks during January–June 1970 was 320 nCi of alpha radioactivity, 7.4 Ci of carbon-14, 49 Ci of tritium and 52 μCi of other beta-particle emitters. The average concentrations in the total exhaust, before any dilution by the atmosphere, was 46 percent of the maximum permissible concentration for offsite breathing zone air, as given by the ICRP.

In addition to the careful sampling of stacks, an environmental air sampling program is also carried on to make sure no undetected releases occur. These samples provide a direct measurement of possible exposure to the nearby population. The sampling stations designated "local area" are scattered around the site and provide samples of the atmosphere on the site itself. The "perimeter" samples are taken at the boundary line of University property, in the direction of populated areas. From the results of these samples, there appears to have been no significant exposure from radioactive materials released by LRL. The levels of radioactivity observed in each type of sample are presented in table 11.

Table 11. Atmospheric monitoring, LRL Berkeley site January–June 1970

Sampling locations (number of locations)	Number of samples	Average concentration (pCi/m³)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (10)	246	0.000	0.005	0.30	1.36
Perimeter					
A	25	.000	<.005	.30	.70
B	23	.000	<.005	.31	.74
C	22	.000	<.005	.32	.74
D	24	.000	<.005	.33	.69
Summary	94	.000	<.005	.32	.74

At each of these environmental stations, rain or dry fallout is also collected. Open 15-inch-diameter polyethylene bags form the collecting vessel. If no rain has fallen, the bags are rinsed out with dilute nitric acid to obtain a sample. Since, on the average, the more remote perimeter stations show about the same radioactivity as the nearer ones, the radioactivity does not result from laboratory operations. The radioactivity levels in samples collected at each location are summarized in table 12.

Table 12. Total deposition, LRL Berkeley site January–June 1970

Sampling locations (number of locations)	Number of samples	Average deposition (nCi/m²)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Local area (9)	54	0.023	0.073	4.58	5.36
Perimeter (4)	24	.035	.066	5.31	6.45

XUM

Table 13. Summary of sewer data, LRL Berkeley site, January–June 1970

Sewer	Total quantities discharged 6 months			Number of samples	Net concentrations (pCi/liter)			
	Total volume (Ml)	Total alpha radioactivity (μCi)	Total beta radioactivity (mCi)		Alpha		Beta	
					Average	Maximum	Average	Maximum
Hearst Sewer	231.6	0	8.49	23	0	1.1	36.7	147
Strawberry Sewer	35.3	76.6	.73	19	2.17	18.8	20.7	136
Summary	266.9	76.6	9.22	42	0.29	18.8	34.6	147

All liquid waste known to be radioactive is collected, solidified, and shipped away. Other liquid wastes are discharged directly to the municipal sewer system. Occasionally, small quantities of radioisotopes are accidentally released to the sewer system. There are two outfalls, each of which is monitored by a continuous proportional sampling system to insure that no significant quantities have been discharged (table 13). The total concentration (alpha-plus-beta radioactivity) in sewage is only 38 percent of the standard for drinking water and therefore does not constitute an exposure threat. A sizeable fraction of the measured beta concentration is the naturally occurring isotope, potassium-40, from human wastes and chemicals.

The storm drainage from the laboratory flows into the surface stream system. These surface streams are exposed as they run through the University property and are sampled at three places. Results are listed as "onsite streams" in table 14. Two nearby offsite streams are also sampled to provide a comparison. All concentrations are less than the standard for drinking water. The results from the water sampling program are presented in table 14.

Neutron and gamma-ray fields are measured at each of the four perimeter stations as well as at several locations within the site. Background measurements are obtained from a leased building used as a low-level counting room in downtown Berkeley. This building is remote from the main LRL site and measurements are not influenced by accelerator operations.

At each station, gamma measurements are made by a recording G-M detector, standardized with a calibrated radium source. These instruments operate unattended and each can operate for 1 week on its internal battery should external power fail.

Table 14. Water monitoring, LRL Berkeley site January–June 1970

Type and source of sample	Number of samples	Concentration (pCi/liter)			
		Alpha radioactivity		Beta radioactivity	
		Average	Maximum	Average	Maximum
Surface water:					
Onsite streams:					
Blackberry	25	0.30	1.6	2.4	7.0
Lower Strawberry	25	.60	4.9	7.8	30
Upper Strawberry	25	.30	4.4	3.2	8.4
Summary	75	.40	4.9	4.5	30
Offsite streams:					
Claremont	25	1.3	12.1	2.8	14
Wildcat	25	.00	1.1	3.0	25
Summary	50	.63	12.1	2.8	25
Tap water	24	.042	.28	1.6	2.9

Several neutron detectors are employed at each station. The primary detector is a BF_3 gas proportional counter in a 2½ inch-thick paraffin-lined moderator. This detector is sensitive in the region from 0.1 to 20 MeV, where 75 percent of the biologically significant neutrons exist. A polyethylene-lined proton recoil neutron detector provides a measure of the energy flux density. The ratio of energy flux density to neutron flux density gives the average neutron energy which allows conversion of the data to dose in rems. Cobalt disks in moderators are maintained as long-term integrating neutron monitors at many sites throughout the laboratory as well as at each perimeter station.

Cosmic ray intensity is continuously monitored by a meson detector with an effective angle

of acceptance of 2.3 steradians (in the upward direction). This provides information on the background neutron levels contributed by cosmic rays.

At each station, total radiation levels are well below the standards set for the general public by the ICRP and the National Council on Radiation Protection and Measurements (NCRP). Results are presented in table 15.

Table 15. Beta-gamma and fast neutron surveillance results, Berkeley site, January–June 1970

Station	Total beta-gamma exposure (mrem) (background subtracted)	Total fast neutron exposure[a] (mrem) (background subtracted)
A	12.9	93.5
B	7.1	33.7
C	4.5	.44
D	5.8	33.8
Downtown Berkeley	[b]	[b]

[a] 2.45×10^7 n/cm² = 1 rem.
[b] Detector not in service.

Livermore site

The Livermore site of LRL (figure 4) is located in the Livermore Valley midway between the Pacific coast and the San Joaquin Valley in northern California, approximately 50 miles southeast of San Francisco. Shielded from the ocean by the western hills, the Livermore Valley has a warm, dry climate. Annual rainfall is about 14 inches and the relative humidity is about 30 percent during the summer months and about 40–50 percent the remainder of the year. Prevailing winds are from the west, but inversions are frequent during the night.

Agriculture is the principal activity in the Livermore Valley. Roses, grain, hay, and grapes are the major products. Several cattle and sheep ranches surround the Livermore site.

The Livermore site comprises an area of 1-square mile, approximately 3 miles east of the city of Livermore. Livermore and Pleasanton, with a combined population of 45,000, are the populated areas of primary interest to the Livermore site.

An environmental sampling program is maintained to provide information regarding the effectiveness of control measures and to determine whether any radiological changes in the environment are the result of laboratory operations. The sampling program includes air particulates, soil, domestic water, sewer effluent, sewage plant products, milk, and vegetation. The milk samples are obtained from one dairy in the Livermore Valley and from another dairy near Site 300.

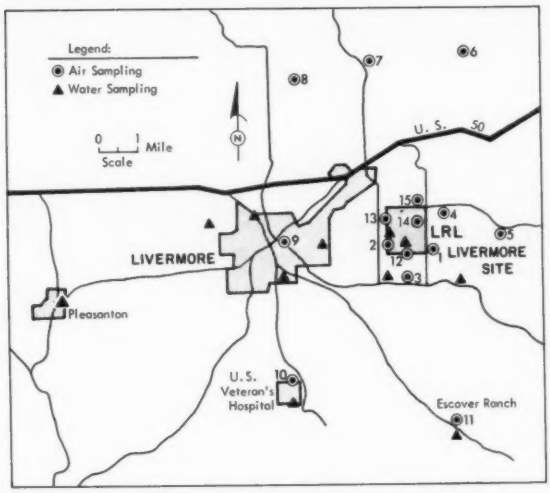

Figure 4. Environmental sampling locations at the Livermore site, Lawrence Radiation Laboratory

Techniques

An automated counting system is used for all environmental air samples. This system utilizes gas-flow proportional detectors for both alpha and beta counting. The alpha detector is approximately 11 percent efficient for the 5.1 MeV alphas of plutonium-239. The efficiency for the 0.54 MeV and 2.27 MeV betas of strontium-90 in equilibrium with yttrium-90 is about 26 percent.

Soil, water, and sewage samples are counted on an automatic low-background system that detects alpha particles with an efficiency of about 34 percent at 5.1 MeV, strontium-yttrium-90 beta particles with an efficiency of approximately 50 percent.

The milk samples are concentrated using a vacuum-operated, foam-entrainment evaporator so that about 9 liters of whole milk are condensed to 2 liters by evaporation. The sample is counted in a plexiglass container placed between two 20-by 10-cm NaI (Tl) crystals. The data are recorded in a multi-channel analyzer and

Table 16. Airborne particulate radioactivity around LRL-Livermore site January–June 1970

Sampling location	Number of samples	Alpha radioactivity[a] (fCi/m³)		Beta radioactivity[a] (fCi/m³)	
		Average	Maximum	Average	Maximum
1	36	≤0.4	1.3	169	453
2	39	≤ .4	≤ .4	161	417
3	24	≤1.0	≤1.0	80	202
4	22	≤1.0	≤1.0	152	278
5	24	≤1.0	≤1.0	114	274
6[b]	—				
7	25	≤1.0	≤1.0	97	256
8	23	≤1.0	≤1.0	81	184
9	23	≤1.0	≤1.0	155	417
10	21	≤1.0	≤1.0	71	199
11	22	≤1.0	≤1.0	72	199
12	36	.4	2.1	212	626
13	38	.4	1.2	156	450
14	36	.4	≤ .4	182	488
15	39	.4	1.3	188	524
16	23	≤1.0	≤1.0	131	514

[a] Approximate limits of sensitivity: Alpha
locations 1, 2, 12–15—4 fCi/m³
locations 3–11, 16—1.0 fCi/m³
Beta
locations 1, 2, 12–15—4 fCi/m³
locations 3–11, 16—10 fCi/m³
Estimated error limits: Alpha radioactivity ± 30 percent
Beta radioactivity ± 20 percent.

[b] Sampler is being relocated.

processed by a computer code using standard spectra taken on the same counting apparatus.

The vegetation samples, taken from nine locations throughout the Livermore Valley, are dried in ambient air for about 1 week. Then, 150–200 grams of dry material are pressed into a pellet, 13 cm diameter by 1.3 to 2.6 cm thick. The pellet is then counted on the system described for milk. The data are also processed by computer.

Samples of environmental water, milk, and vegetation are analyzed for tritium. One milliliter of water or distillate is counted in a liquid scintillation counter having a 32 percent efficiency for HTO.

The soil samples are prepared by digesting 1 gram of material in a mixture of perchloric and nitric acids and evaporating to near dryness. The resulting residue is redissolved in a hydrogen peroxide and nitric acid mixture and subsequently plated onto stainless-steel plates. The water and sewage samples, of one-half liter volume, are treated similarly.

Air and soil samples are collected to ascertain that control efforts are restricting the release of radioactivity from the laboratory to levels that do not exceed the permissible levels for the neighborhood around an atomic energy facility. The water samples are collected to ascertain that radioactivity is not entering the underground water supply which provides most of the domestic water for the cities of Livermore and Pleasanton, the sole supply for ranches in the Livermore and Amador Valleys. Samples were taken at the Livermore Sewage Disposal Plant to establish that liquid effluent from the laboratory is not contributing significant radioactivity to the dried sludge or liquid effluent produced. The dried sludge is used as an agricultural soil conditioner. Some liquid effluent released to the Los Positas Arroyo is used for irrigation of the golf course turf and some agricultural land.

Air samples are collected continuously at 15 sites within 5 miles of the laboratory. Samples are collected at a rate of 4 cfm on 100-square centimeter HV-70 filter papers, which are changed after every 7 days of operation. A minimum decay period of 4 days is observed before the samples are counted to eliminate the effect of natural radon and thoron daughters (table 16). The average airborne beta radioactivity was 0.1 pCi/m³, about the same as that reported during the previous 6 months.

The measurement of low level "background" radiation was accomplished with thermolumines-

cent dosimeters located at nine points on the site perimeter and at three offsite locations. The limit of detection for these dosimeters is 10 mR. The three offsite locations had dose recordings of 10 mR for the past 6 month period. At the nine locations around the controlled area perimeter, doses of 10 mR were recorded at all the locations except locations 3 and 5 (table 17).

Table 17. External gamma radiation measurements LRL Livermore site, January–June 1970

Dosimeter location[a]	Exposure (mR)
1	10
2	10
3	24
4	10
5	35
6	10
7	10
8	10
9	10
10	10
11	10
12	10

[a] Locations 1–9—controlled area perimeter.
Locations 10, 11, and 12—uncontrolled area.

Domestic water samples were collected monthly from nine nearby sources. No samples showed an alpha radioactivity above the limit of detection (5.0 pCi/liter). The beta radioactivity is shown in table 18. The tritium concentrations in water samples were below the limit of detection (5 nCi/liter).

Table 18. Beta radioactivity in domestic water supplies, LRL Livermore site, January–June 1970

Dosimeter location	Beta radioactivity[a] (pCi/liter)	
	Maximum	Average
1	7.2	1.9
2	10.9	4.7
3	9.1	2.3
4	7.2	1.8
5	4.5	1.9
6	1.8	1.8
10	20.5	4.2
Building 254 (LRL)	20.4	6.4
Building 419 (LRL)	42.3	9.6

[a] The limit of detection for gross beta radioactivity is 1.8 pCi/liter.

Samples were collected daily at the laboratory sewer discharge. The results of the analyses of these samples are given in table 19. The average alpha radioactivity concentration in the sewer effluent ranged between 3.5 and 20 pCi/liter, while the monthly average beta radioactivity varied between 130 and 760 pCi/liter. The average tritium content of the effluent ranged between 11 and 160 nCi/liter with a maximum of 1,800 nCi/liter. The effluent was also analyzed for strontium-90, radium-226, -228, and iodine radioisotopes.

Table 19. Radioactivity in laboratory sewer effluent samples, January–June 1970

Month (1970)	Alpha radioactivity (pCi/liter)		Beta radioactivity (pCi/liter)		Tritium (nCi/liter)		Average concentrations			
	Maximum	Average	Maximum	Average	Maximum	Average	Strontium-90 (pCi/liter)	Radium-226 (fCi/liter)	Radium-228 (pCi/liter)	Mixed iodine (pCi/liter)
January	51	7.6	2,300	452	100	18	37	49	8.6	7.7
February	56	7.0	3,350	560	64	11	49	75	11	13.5
March	43	4.6	1,120	260	1,180	160	6.2	51	1.3	18.5
April	15	3.5	585	130	580	41	6.9	49	1.5	.4
May	280	20	8,000	760	590	51	36	66	1.7	1
June	64	20	705	183	41	25	2.9	29	12	1

Table 20. Radioactivity in samples from the Livermore Sewage Disposal Plant, January–June 1970

Month (1970)	Gross alpha radioactivity (pCi/liter)						Gross beta radioactivity (pCi/liter)					
	Digesters		Aeration tank		Effluent		Digesters		Aeration tank		Effluent	
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
January	440	323	62	32	<5	<5	7,780	3,080	370	240	77	27
February	475	240	75	57	<5	<5	5,110	2,510	540	328	127	55
March	381	182	65	35	<5	<5	2,810	2,040	4,140	1,240	110	46
April	334	190	67	39	<5	<5	3,120	1,890	263	175	180	46
May	358	249	83	55	<5	<5	6,780	3,860	1,140	697	2,060	271
June	457	262	248	136	<5	<5	3,080	2,090	540	452	79	59

XUM

When the sewage from the laboratory and city of Livermore enters the sewage disposal plant, the liquid and sludge are separated. The sludge passes into one of two digesters where it is broken down by bacterial action. Methane gas is evolved and burned, and the remaining sludge is released to large sludge lagoons and/or drying beds and is retained for subsequent possible use as a soil conditioner. The purified water is used on the Livermore golf course and for agricultural irrigation on a nearby farm; the excess is discharged into the Los Positas Arroyo. Samples were collected weekly from the aeration tanks, each digester, and the effluent to the arroyo. The results of these analyses are given in table 20.

Samples of top-layer soil are collected quarterly at the 19 sampling locations in the Livermore Valley. The alpha radioactivity of each sample was less than the limit of detection (1.5 pCi/g). The beta radioactivity fluctuated from the limit of detection (3.5 pCi/g) to 15.5 pCi/g, averaging 5.4 pCi/g. The concentrations detected are within the normal range for soil in the Livermore Valley, as determined from surveillance during previous years.

Average radioactivity levels in monthly milk samples from the dairy near the Livermore site were 5.1 pCi/liter of cesium-137, 8.9 nCi/liter for tritium, and no detectable concentrations of cerium-141,-144. For the dairy near Site 300, the average concentrations were 1.4 pCi/liter, 8.8 nCi/liter and undetectable for cesium-137, tritium, and cerium-141,-144, respectively.

Vegetation samples were collected during January–June of 1970. The radioactivity of 15 unwashed grass samples and three eucalyptus leaf samples is presented in table 21. A portion of each sample was freeze-dried, and the water collected was analyzed for HTO.

Continuous radioactive air sampling is maintained on the effluent from stacks of operations that are potential sources of radioactive material releases. These facilities include the hot cells, transuranic chemistry, plutonium metallurgy, and the reactor building. The effluent from these buildings passes through an absolute filter prior to being exhausted to the atmosphere. Analysis of samples from the stack monitoring system indicates that the permissible offsite concentrations were not exceeded as a result of stack effluent during the past 6 months. The radioactivity in the environment remained below the appropriate AEC concentration guide levels. The gross alpha and beta radioactivities contained in samples of airborne particulate debris, soil, water, and sewage leaving the laboratory were at the levels normally observed for these samples. The milk and vegetation samples showed no gamma-emitting radionuclides other than those present in the current worldwide fallout inventory. Their activities were similar to those normally observed for these nuclides. The stack sampling program indicated that laboratory operations did not contribute any of significant quantities of radioactivity to the environment. The data indicated the LRL radiological control measures were successful in preventing significant contribution of radioactive material to the environment around the laboratory site during this period.

Table 21. Radioactivity in vegetation, LRL Livermore site, January–June 1970

Nuclide	Concentration[a] (pCi/g dry weight)				Limit of detection
	Grass		Eucalyptus leaves		
	Average	Maximum	Average	Maximum	
Beryllium 7	≤0.01	≤0.01	≤0.01	≤0.01	0.01
Manganese-54	.05	.10	.02	.03	.01
Zirconium-95	.53	.90	.10	.16	.01
Ruthenium-103, -106	.28	.64	.06	.08	.02
Antimony-125	.15	.38	.06	.10	.02
Cesium-137	≤ .01	≤ .01	≤ .01	≤ .01	.01
Cerium-141, -144	1.17	2.86	.34	.40	.02
Tritium[a]	≤5	8.2	<5	<5	5

[a] Except tritium which is in nCi/liter of water.

Site 300

The high explosive test area at Site 300 (figure 5) covers 10 square miles in the hills in a very sparsely populated ranching area about 15 miles southeast of Livermore and 8 miles southwest of Tracy. The chief area of concern for Site 300 is Tracy with a population of about 15,000. Air and water samples are taken to determine whether operations at Site 300 are changing the normal radioactivity levels in the vicinity. The 11 air samplers at Site 300 are operated on a continuous basis at about 50 cfm, and the filter papers are changed regularly. Most of these air samplers are

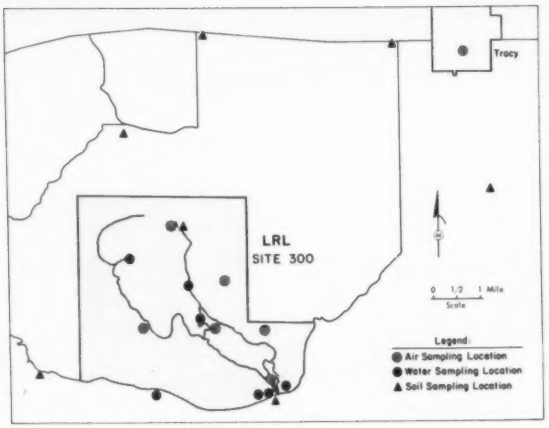

Figure 5. Sampling locations at Site 300, LRL

located within the boundaries of the test site due to unavailability of electric power facilities offsite. Table 22 gives the airborne particulate radioactivity for January–June 1970. Water samples are collected monthly from onsite wells. Streams in the area are sampled when they contain water (usually during the winter). No sample showed an alpha radioactivity concentration above the limit of detection (5.0 pCi/liter). The average beta concentrations ranged from 2.3 pCi/liter to 8.3 pCi/liter, with a maximum single sample concentration of 16.3 pCi/liter.

Soil samples are collected quarterly at nine offsite locations. The alpha radioactivity ranged from 1.5 pCi/g (the limit of detection) to 1.9 pCi/g. The beta radioactivity ranged from the limit of detection (3.5 pCi/g) to 16 pCi/g, with an average activity of 7.9 pCi/g.

Table 22. Airborne particulate radioactivity LRL Site 300, January–June 1970

Sampling location	Number of samples	Alpha radioactivity[a] (fCi/m³)		Beta radioactivity[a] (fCi/m³)	
		Average	Maximum	Average	Maximum
1[b]	14	<0.2	<0.2	136	521
2	36	< .2	1.0	194	489
3	32	< .2	< .2	212	704
4	38	< .2	< .2	232	755
5	39	< .2	1.2	209	610
6	20	< .2	< .2	139	362
7	35	<1.0	<1.0	198	596
8	39	< .2	< .2	222	693
9	37	< .2	1.1	240	927
10	34	< .2	1.0	235	661
11	26	< .2	< .2	221	549
Summary	350	<0.2	1.2	203	927

[a] Limit of detection—alpha radioactivity—location 1–6, 8–11, 0.2 fCi/m³. location 7, 1.0 fCi/m³.
beta radioactivity—location 1–6, 8–11, 2 fCi/m³. location 7, 10 fCi/m³.
Variations in limits of detection result from differing flow rates. Estimated error limits—alpha radioactivity, ±30 percent
beta radioactivity, ±20 percent.
[b] Sampler inoperative for several weeks.

None of the average concentrations of air, water, and soil samples exceeded the standards of comparison applicable to activities at the test site, nor did any of the results increase significantly compared to 1969 data. Therefore, it appears that radiological control measures at Site 300 were adequate and that no significant radioactivity was released to the environment near the site during this period.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January—June 1969	April 1970
July—December 1969	November 1970

XUM

Reported Nuclear Detonations, April 1971

(Includes seismic signals presumably from foreign nuclear detonations)

No nuclear detonations were reported by the U.S. Atomic Energy Commission for April 1971.

The U.S. Atomic Energy Commission announced that the United States had recorded seismic signals, presumably from a Soviet underground nuclear explosion on April 24, 1971. The signals originated at approximately 10:33 EST, at the Semipalatinsk nuclear test area and were equivalent to those of an underground nuclear explosion in the yield range of 20–200 kilotons.

Information in this section is based on data received during the month, and is subject to change as additional information may become available. Persons requiring information for purposes of compiling announced nuclear detonation statistics are advised to contact the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

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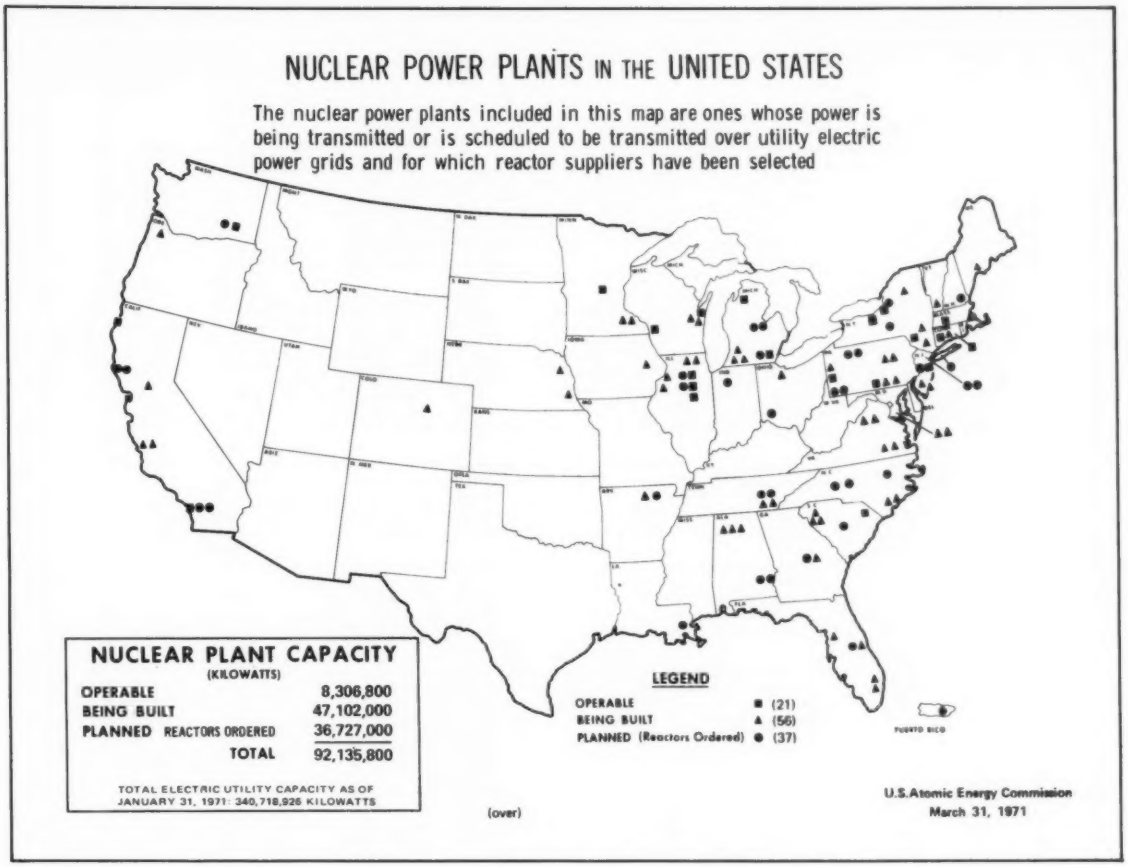
NUCLEAR POWER PLANTS IN THE UNITED STATES
The nuclear power plants included in this map are ones whose power is being transmitted or is scheduled to be transmitted over utility electric power grids and for which reactor suppliers have been selected
NUCLEAR PLANT CAPACITY
(KILOWATTS)
OPERABLE 8,306,800
BEING BUILT 47,102,000
PLANNED REACTORS ORDERED 36,727,000
TOTAL 92,135,800
TOTAL ELECTRIC UTILITY CAPACITY AS OF JANUARY 31, 1971: 340,718,926 KILOWATTS
LEGEND
OPERABLE ■ (21)
BEING BUILT ▲ (56)
PLANNED (Reactors Ordered) ● (37)
PUERTO RICO
(over)
U.S.Atomic Energy Commission
March 31, 1971

Figure 1. Nuclear power plants in the United States

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	INITIAL DESIGN POWER
ALABAMA				
Decatur	Browns Ferry Nuclear Power Plant: Unit 1	1,065,000	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 2	1,065,000	Tennessee Valley Authority	1972
Decatur	Browns Ferry Nuclear Power Plant: Unit 3	1,065,000	Tennessee Valley Authority	1973
Dothan	Joseph M. Farley Nuclear Plant: Unit 1	829,000	Alabama Power Co.	1975
Dothan	Joseph M. Farley Nuclear Plant: Unit 2	829,000	Alabama Power Co.	1977
ARKANSAS				
London	Arkansas Nuclear One: Unit 1	820,000	Arkansas Power & Light Co.	1973
London	Arkansas Nuclear One: Unit 2	920,000	Arkansas Power & Light Co.	1975
CALIFORNIA				
Humboldt Bay	Humboldt Bay Power Plant: Unit 3	68,500	Pacific Gas & Electric Co.	1963
San Clemente	San Onofre Nuclear Generating Station: Unit 1	430,000	So. Calif. Ed. & San Diego Gas & El. Co.	1967
San Clemente	San Onofre Nuclear Generating Station: Unit 2	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1975
San Clemente	San Onofre Nuclear Generating Station: Unit 3	1,140,000	So. Calif. Ed. & San Diego Gas & El. Co.	1977
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 1	1,060,000	Pacific Gas & Electric Co.	1973
Diablo Canyon	Diablo Canyon Nuclear Power Plant: Unit 2	1,060,000	Pacific Gas & Electric Co.	1974
Clay Station	Rancho Seco Nuclear Generation Station	804,000	Sacramento Municipal Utility District	1972
Pt. Arena	Mendocino Power Plant: Unit 1	1,128,000	Pacific Gas & Electric Co.	1977
Pt. Arena	Mendocino Power Plant: Unit 2	1,128,000	Pacific Gas & Electric Co.	1979
COLORADO				
Platteville	Ft. St. Vrain Nuclear Generating Station	330,000	Public Service Co. of Colorado	1972
CONNECTICUT				
Haddam Neck	Haddam Neck Plant	575,000	Conn. Yankee Atomic Power Co.	1967
Waterford	Millstone Nuclear Power Station: Unit 1	652,100	Northeast Utilities	1971
Waterford	Millstone Nuclear Power Station: Unit 2	828,000	Northeast Utilities	1974
FLORIDA				
Turkey Point	Turkey Point Station: Unit 3	693,000	Florida Power & Light Co.	1971
Turkey Point	Turkey Point Station: Unit 4	693,000	Florida Power & Light Co.	1972
Red Level	Crystal River Plant: Unit 3	858,000	Florida Power Corp.	1972
Ft. Pierce	Hutchinson Island: Unit 1	800,000	Florida Power and Light Co.	1974
Ft. Pierce	Hutchinson Island: Unit 2	800,000	Florida Power and Light Co.	1976
GEORGIA				
Baxley	Edwin I. Hatch Nuclear Plant: Unit 1	786,000	Georgia Power Co.	1973
Baxley	Edwin I. Hatch Nuclear Plant: Unit 2	786,000	Georgia Power Co.	1976
ILLINOIS				
Morris	Dresden Nuclear Power Station: Unit 1	200,000	Commonwealth Edison Co.	1960
Morris	Dresden Nuclear Power Station: Unit 2	809,000	Commonwealth Edison Co.	1970
Morris	Dresden Nuclear Power Station: Unit 3	809,000	Commonwealth Edison Co.	1971
Zion	Zion Nuclear Plant: Unit 1	1,050,000	Commonwealth Edison Co.	1972
Zion	Zion Nuclear Plant: Unit 2	1,050,000	Commonwealth Edison Co.	1973
Cordova	Quad-Cities Station: Unit 1	809,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1971
Cordova	Quad-Cities Station: Unit 2	809,000	Comm. Ed. Co.-Ia.-Ill. Gas & Elec. Co.	1972
Seneca	LaSalle Co. Nuclear Station: Unit 1	1,078,000	Comm. Ed. Co.-Ia.	1975
Seneca	LaSalle Co. Nuclear Station: Unit 2	1,078,000	Comm. Ed. Co.-Ia.	1976
INDIANA				
Dune Acres	Bailly Generating Station	660,000	Northern Indiana Public Service Co.	1976
IOWA				
Cedar Rapids	Duane Arnold Energy Center: Unit 1	529,700	Iowa Electric Light and Power Co.	1973
LOUISIANA				
Taft	Waterford Generating Station: Unit 1	1,165,000	Louisiana Power & Light Co.	1976
MAINE				
Wiscasset	Maine Yankee Atomic Power Plant	790,000	Maine Yankee Atomic Power Co.	1972
MARYLAND				
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 1	845,000	Baltimore Gas and Electric Co.	1973
Lusby	Calvert Cliffs Nuclear Power Plant: Unit 2	845,000	Baltimore Gas and Electric Co.	1974
MASSACHUSETTS				
Rowe	Yankee Nuclear Power Station	175,000	Yankee Atomic Electric Co.	1961
Plymouth	Pilgrim Station	655,000	Boston Edison Co.	1971
MICHIGAN				
Big Rock Point	Big Rock Point Nuclear Plant	70,300	Consumers Power Co.	1963
South Haven	Palisades Nuclear Power Station	700,000	Consumers Power Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 1	60,900	Detroit Edison Co.	1970
Lagoona Beach	Enrico Fermi Atomic Power Plant: Unit 2	1,123,000	Detroit Edison Co.	1973
Bridgman	Donald C. Cook Plant: Unit 1	1,054,000	Indiana & Michigan Electric Co.	1973
Bridgman	Donald C. Cook Plant: Unit 2	1,060,000	Indiana & Michigan Electric Co.	1974
Midland	Midland Nuclear Power Plant: Unit 1	492,000	Consumers Power Co.	1976
Midland	Midland Nuclear Power Plant: Unit 2	818,000	Consumers Power Co.	1977
MINNESOTA				
Monticello	Monticello Nuclear Generating Plant	545,000	Northern States Power Co.	1971
Red Wing	Prairie Island Nuclear Generating Plant: Unit 1	530,000	Northern States Power Co.	1972
Red Wing	Prairie Island Nuclear Generating Plant: Unit 2	530,000	Northern States Power Co.	1974
* Site not selected.				
*	—	1,201,000	Tennessee Valley Authority	1977
*	—	1,201,000	Tennessee Valley Authority	1978

Figure 1. Nuclear power plants in the United States—Continued

SITE	PLANT NAME	CAPACITY (Net Kilowatts)	UTILITY	INITIAL DESIGN POWER
NEBRASKA				
Fort Calhoun	Ft. Calhoun Station: Unit 1	457,400	Omaha Public Power District	1972
Brownville	Cooper Nuclear Station	778,000	Nebraska Public Power District and Iowa Power and Light Co.	1973
NEW JERSEY				
Toms River	Oyster Creek Nuclear Power Plant: Unit 1	560,000	Jersey Central Power & Light Co.	1969
Lacey Township	Forked River Generating Station: Unit 1	1,140,000	Jersey Central Power & Light Co.	1975
Salem	Salem Nuclear Generating Station: Unit 1	1,050,000	Public Service Electric and Gas, N. J.	1973
Salem	Salem Nuclear Generating Station: Unit 2	1,050,000	Public Service Electric and Gas, N. J.	1974
Newbold Island	Newbold Nuclear Generating Station: Unit 1	1,088,000	Public Service Electric and Gas, N. J.	1975
Newbold Island	Newbold Nuclear Generating Station: Unit 2	1,088,000	Public Service Electric and Gas, N. J.	1977
NEW YORK				
Indian Point	Indian Point Station: Unit 1	265,000	Consolidated Edison Co.	1963
Indian Point	Indian Point Station: Unit 2	873,000	Consolidated Edison Co.	1971
Indian Point	Indian Point Station: Unit 3	965,000	Consolidated Edison Co.	1973
Scriba	Nine Mile Point Nuclear Station	500,000	Niagara Mohawk Power Co.	1970
Rochester	R. E. Ginna Nuclear Power Plant: Unit 1	420,000	Rochester Gas & Electric Co.	1970
Brookhaven	Shoreham Nuclear Power Station	819,000	Long Island Lighting Co.	1975
Lansing	Bell Station	838,000	New York State Electric & Gas Co.	1978
Verplanck	Verplanck: Unit 1	1,115,000	Consolidated Edison Co.	1977
Scriba	James A. Fitzpatrick Nuclear Power Plant	821,000	Power Authority of State of N. Y.	1973
NORTH CAROLINA				
Southport	Brunswick Steam Electric Plant: Unit 1	821,000	Carolina Power and Light Co.	1976
Southport	Brunswick Steam Electric Plant: Unit 2	821,000	Carolina Power and Light Co.	1974
*		821,000	Carolina Power and Light Co.	–
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 1	1,150,000	Duke Power Co.	1975
Cowans Ford Dam	Wm. B. McGuire Nuclear Station: Unit 2	1,150,000	Duke Power Co.	1976
OHIO				
Oak Harbor	Davis-Besse Nuclear Power Station	872,000	Toledo Edison-Cleveland Electric Illuminating Co.	1974
Moscow	Wm. H. Zimmer Nuclear Power Station: Unit 1	810,000	Cincinnati Gas & Electric Co.	1974
OREGON				
Rainier	Trojan Station	1,130,000	Portland General Electric Co.	1974
PENNSYLVANIA				
Peach Bottom	Peach Bottom Atomic Power Station: Unit 1	40,000	Philadelphia Electric Co.	1967
Peach Bottom	Peach Bottom Atomic Power Station: Unit 2	1,065,000	Philadelphia Electric Co.	1972
Peach Bottom	Peach Bottom Atomic Power Station: Unit 3	1,065,000	Philadelphia Electric Co.	1973
Pottstown	Limerick Generating Station: Unit 1	1,065,000	Philadelphia Electric Co.	1975
Pottstown	Limerick Generating Station: Unit 2	1,065,000	Philadelphia Electric Co.	1977
Shippingport	Shippingport Atomic Power Station: Unit 1	90,000	Duquesne Light Co.	1957
Shippingport	Beaver Valley Power Station: Unit 1	847,000	Duquesne Light Co.-Ohio Edison Co.	1973
Middletown	Three Mile Island Nuclear Station: Unit 1	810,000	Metropolitan Edison Co.	1972
Middletown	Three Mile Island Nuclear Station: Unit 2	831,000	Jersey Central Power & Light Co.	1974
Berwick	Susquehanna Steam Electric Station: Unit 1	1,052,000	Pennsylvania Power and Light	1977
Berwick	Susquehanna Steam Electric Station: Unit 2	1,052,000	Pennsylvania Power and Light	1979
SOUTH CAROLINA				
Hartsville	H. B. Robinson S. E. Plant: Unit 2	700,000	Carolina Power & Light Co.	1971
Seneca	Oconne Nuclear Station: Unit 1	841,000	Duke Power Co.	1971
Seneca	Oconee Nuclear Station: Unit 2	886,000	Duke Power Co.	1972
Seneca	Oconee Nuclear Station: Unit 3	886,000	Duke Power Co.	1973
Parr	–	900,000	South Carolina Electric & Gas Co.	1977
TENNESSEE				
Daisy	Sequoyah Nuclear Power Plant: Unit 1	1,124,000	Tennessee Valley Authority	1974
Daisy	Sequoyah Nuclear Power Plant: Unit 2	1,124,000	Tennessee Valley Authority	1974
Spring City	Watts Bar Nuclear Plant: Unit 1	1,170,000	Tennessee Valley Authority	1976
Spring City	Watts Bar Nuclear Plant: Unit 2	1,170,000	Tennessee Valley Authority	1977
VERMONT				
Vernon	Vermont Yankee Generating Station	513,900	Vermont Yankee Nuclear Power Corp.	1971
VIRGINIA				
Gravel Neck	Surry Power Station: Unit 1	780,000	Virginia Electric & Power Co.	1971
Gravel Neck	Surry Power Station: Unit 2	780,000	Virginia Electric & Power Co.	1972
Mineral	North Anna Power Station: Unit 1	845,000	Virginia Electric & Power Co.	1974
Mineral	North Anna Power Station: Unit 2	845,000	Virginia Electric & Power Co.	1975
WASHINGTON				
Richland	N-Reactor/WPPSS Steam	790,000	Washington Public Power Supply System	1966
Richland	Hanford No. 2	1,135,000	Washington Public Power Supply System	1977
WISCONSIN				
Genoa	LaCrosse Boiling Water Reactor	50,000	Dairyland Power Cooperative	1969
Two Creeks	Point Beach Nuclear Plant: Unit 1	497,000	Wisconsin Michigan Power Co.	1970
Two Creeks	Point Beach Nuclear Plant: Unit 2	497,000	Wisconsin Michigan Power Co.	1971
Carlton	Kewaunee Nuclear Power Plant: Unit 1	540,000	Wisconsin Public Service Co.	1972
PUERTO RICO				
Puerto De Jobas	Aguirre Nuclear Power Plant	583,000	Puerto Rico Water Resources Authority	1975

Figure 1. Nuclear power plants in the United States—Continued

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ENVIRONMENTAL MONITORING AND DISPOSAL OF RADIOACTIVE WASTES FROM U.S. NAVAL NUCLEAR-POWERED SHIPS AND THEIR SUPPORT FACILITIES, 1970. *M. E. Miles, J. J. Mangeno, and R. D. Burke. Radiological Health Data and Reports*, Vol. *12*, May 1971, pp. 235–244.

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm adequacy of waste disposal limits and procedures. The total radioactivity discharged into all ports and harbors was 24 millicuries in 1970, less than one hundredth the total annual discharges of the early 1960's. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt-60 show that (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase in the general background radioactivity of the environment, and (3) low-level cobalt-60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years; these levels have decreased in recent years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities have been effective in protecting the health and safety of the general public.

KEYWORDS: Discharges, disposal, harbors, monitoring, nuclear-powered ships, radioactivity, U.S. Navy, wastes.

RADIATION EXPOSURE TO A PHANTOM PATIENT DURING SIMULATED CHIROPRACTIC SPINAL RADIOGRAPHY. *J. I. Levine, J. W. Howe,* and *J. W. Rolofson. Radiological Health Data and Reports*, Vol. *12*, May 1971, pp. 245–251.

Radiographic exposures to various organs of a simulated patient were determined for 31 techniques of spinal radiography used by doctors of chiropractic. It was determined that the radiation exposure from the most commonly used techniques would be reduced by changing to techniques using higher filtration, higher kilovoltage with reduced milliampere-seconds, and smaller beam areas. The use of split or graduated screens, step wedges, and masks also reduced radiation exposure to the simulated patient without reducing the radiographic quality of the films.

KEYWORDS: Chiropractor, exposure, phantom, radiographic techniques, radiography, spine, x-ray.

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